Participation in Global Value Chains: The impact of distance and national transportation systems

Angela Stefania Bergantino[1*], Ada Spiru[2]

[1] *Department of Economics, Management and Business Law - University of Bari Aldo Moro, Italy*
[2] *Department of Economics, Management and Business Law - University of Bari Aldo Moro, Italy*

Abstract

Trade is becoming increasingly fragmented and global value chains (GVCs) more complex. Although GVCs are often considered a defining feature of the current wave of globalization, little is known about what drives GVC participation. This yields to the question what separate less successful countries from successful ones. The increased geographic spread of production processes induces an increasing importance of physical transportation of input and output goods. For emerging economies, increasing international trade and enhancing the participation in global value chains (GVC) are high priority objectives (Percoco, 2014; Bensassi et al., 2015; Rao & Dhar, 2018). In order to achieve them it is necessary to improve the national transportation system and its performance as accessibility is considered an important driver of a country's attractiveness in today's globalized production network (Memedovic et al., 2008; Bosker and Westbrock, 2014).
This work aims to investigate the determinants of the integration in international production networks of both emerging and developed markets in a transport economic perspective. Starting from the assumption that trade between two countries is conditional on several characteristics of the countries involved that can either enhance or hinder bilateral business activities (Zwinkels & Beugelsdijk, 2010), by implementing an augmented gravity equation (Santos Silva and Tenreyro, 2011; Correia et al., 2019), we investigate the role of the national transportation system in moderating the effects of different between-country distance dimensions on GVC-related trade flows. We take into consideration, with a trade policy focus, various aspects of "distance": geographical, institutional, cultural and economic.
We argue that additional costs arising from the different distance dimensions are partly moderated by the host country's national transportation system. Using information provided by the World Input-Output Database (WIOD) for the period 2000-2014, integrated with other data sources, we bring empirical evidence in support of the hypothesis that the national transportation system moderates the effects of between-country distances and reduces the "remoteness" of emerging economies in the global production network participation. Physical gravity factors are found to be significant drivers of vertical trade. We also find evidence confirming that the national transportation system plays an important role in determining countries' vertical trade integration.

Keywords: Transport infrastructure, Global value chains, emerging and developed economies, gravity model.

[*] Autore a cui spedire la corrispondenza: Name Family Name (mail@mail.mail)

1. Introduction

The success or failure of an economy can be largely ascribed to the performance of its enterprises (North and Thomas, 1973; McMillan and Woodruff, 2002; Lewis 2003). From an empirical point of view, the pioneering work of Birch (1981) shows that firms are the main driver of job creation and, hence, of a country's economic growth. His work has been followed by others that further document the role of firms in promoting economic growth and development (Brock and Evans, 1989; Malecki, 1994; Arzeni, 1997; Audretsch and Thurik, 2000; Reynolds et al., 2001; Audretsch and Fritsch, 2002). This body of literature has its origins in Schumpeter's (1934) theory of endogenous growth, which argues that in order to promote economic growth, it is essential to understand the determinants of entrepreneurial performance and to encourage it. Indeed, the development of a country starts from the bottom (Caplan, 1994), and "development-from-below" relies significantly on local resources, enterprises and actors (Helmesing, 2005).

Trade is becoming increasingly fragmented and global value chains (GVCs) more complex. Fragmentation of the production across borders has become an important feature of the global economy over the last twenty years. As well as, increasing international trade and the participation in the global value chains is of high priority for many emerging economies (Rao & Dhar, 2018), while improving the national transportation system is a prerequisite for enhancing the participation is such global production networks (Bosker and Westbrock, 2014)

From the viewpoint of development economics, benefits of GVCs participation can vary considerably depending on whether a country operates at the high or at the low end of the value chain (Baldwin et al, 2014). Despite GVCs are often considered a defining feature of the current wave of globalization, little is known about what drives GVC participation, what the benefits associated to growing participation are or how countries engage and benefit from GVCs. This yields to the question what separate less successful countries from successful ones.

The increased geographic spread of production processes induces an increasing importance of physical transportation of inputs and outputs. The performance of the transportation system (Memedovic et al., 2008) is considered an important driver of a country's attractiveness in today's globalized production network. This is especially true for developing countries for which transportation infrastructure is a key determinant of attractiveness and competitiveness (Percoco, 2014; Bensassi et al., 2015).

This work aims to investigate the determinants of integration in the international production network for both emerging and developed economies in a transport economics perspective. Starting from the assumption that trade between two countries is conditional on several characteristics of the countries involved that can either enhance or hinder bilateral business activities (Zwinkels & Beugelsdijk, 2010), by implementing a gravity model, we investigate the impact of the quality and efficiency of the transportation system of a country on the participation on GVCs, without overlooking the importance of geographical, institutional, cultural and economic distances between the countries involved. We argue that additional costs arising from the different distance dimensions are partly moderated by the host country's national transportation system. Our objective is to shed more light on the importance of individual aspects of the national transport systems on increasing the GVCs participation. We provide empirical evidence that national transportation systems moderate the effects of different dimensions of between-country distances on the participation on the global production network.

The information used are provided by the World Input-Output Database (WIOD) released in 2016. The data covers 28 EU countries and 15 other major countries in the world and 56 sectors for the period from 2000 to 2014, a period during which international production networks and trade liberalization both spread rapidly.

We estimate the gravity model, where controlling for the participation on the GVCs across countries, we find that the typical gravity factors are significant drivers of vertical trade. Of greater interest, the econometric results also confirm that the national transportation system plays an important role in determining countries' vertical trade integration.

First, we provide theoretical arguments and empirical evidence that national transportation systems moderate the effects of the different dimensions of (between-) country distance on GVCs involvement, and more generally on international trade. The detailed knowledge on these effects will help to develop a deeper understanding of factors that shape GVCs.

Second, in today's globalized world, GVCs combine geographically distributed production networks with international trade links. All these networks and links depend on the quality and efficiency of the transportation system. By providing evidence on the relevance of transportation systems for GVCs participation, our study reflects a broader perspective on the building blocks of GVCs.

Third, in our approach we disaggregate the effects of national transportation systems into different modes of transportation. Combined with the first and second contribution, this detailed level of analysis allows policy makers to make better-informed decisions regarding the development of national transportation systems within their home countries.

The work is structured in 5 further sections following this introduction. In Section 2 the literature review on the relationship between trade integration and transportation system is developed. Based on the conceptual framework, the hypothesis to test the ability of national transportation system to reduce the costs of distance are set out. Section 3 outlines the empirical framework and data used in the analysis, followed by Section 4 where the econometric analysis and results on the relationship between GVCs participation and transportation system are presented. Finally, in Section 5 some further conclusions and remarks are discussed.

2. Literature review

World trade and production are increasingly structured around "global value chains" (GVCs). As different stages of production are increasingly performed in different countries leading to the so-called *death of distance* (Cairncross, 1997), the associated cross-border trade, or vertical trade, has come to predominate world trade (Arndt and Kierzkowski, 2001; Gereffi et al., 2001; Baldwin, 2012; OECD, 2013). The phenomenon has been called fragmentation, unbundling, offshoring, vertical specialization, slicing up of the value-added chain or trade in tasks (WTO, 2008).

The concept of GVC was introduced in the early 2000s and has been successful in capturing several characteristics of the world economy, such as the increasing fragmentation of production across countries and the specialization of countries in tasks and business functions rather than specific products. Global value chains link geographically dispersed activities in a single industry and help to understand shifting patterns of trade and production. For policymakers, global value chains are useful to apprehend the interconnectedness of economies. While most policies still assume that goods and services are produced domestically and compete with “foreign” products, the reality is that most goods and an increasing number of services are “made in the world” and that countries compete on economic roles within the value chain.

Hummels et al. (2001) introduced the concept of “vertical specialization” which requires three characteristics, the third of which distinguishes a value chain from simple outsourcing: (1) goods are produced in stages; (2) two or more countries provide value added in the production sequence; (3) at least one country uses imported inputs in its stage of the production process and exports some of the resulting product to either a third country or back to the country of origin. As a result, economic activity has become more interconnected and complex, with potentially important implications for economic policies (OECD, 2013).

Fragmentation and internationalization of production processes seem to have recently taken a more global dimension through their increased expansion towards emerging and developing economies. Unbundling of tasks and specialization in some activities have opened opportunities to those country entrepreneurs and workers to participate in the global economy without having to develop a complete product or value chain (Stamm, 2004; Baldwin, 2012; Escaith, 2014; OECD, 2013) drawing on foreign knowledge and learning by doing (Hausmann, 2014).

Particularly since 2001, the expansion of vertical trade networks and global supply chains has increasingly involved emerging economies, largely in response to infrastructure-induced declines in trade costs (Brooks and Hummels, 2009). Moreover, value chains tend to be very competitive and versatile and the capacity of developing country workers and firms to participate in beneficial ways is not to be taken for granted (e.g. UNCTAD, 2013; Bamber et al., 2014). Some pre-conditions for integration into GVCs of these countries are required. Development of human capital through education and training, developing infrastructure, improving the availability of capital, improving the business climate and scaling up the quality of institutions have also been identified as important factors in enabling integration into GVCs (OECD, 2013; Bamber et al., 2014).

Even if there are scholars that believe international value chains are to be considered as just more trade and division of capital and labour happening at a finer level (Mankiw and Swagel, 2006), most others argue that the emergence of GVC trade requires a wiser thinking on trade and investment (Blinder, 2006; Baldwin, 2009; Grossman and Rossi-Hansberg, 2008).

The level of fragmentation of production can be explained by the technical characteristics of products and the costs incurred when the production is split in different locations (deBacker and Miroudot, 2014). Moreover, the level of fragmentation depends on a trade-off between lower production costs and higher transactions/co-ordination costs (Jones and Kierzkowski, 2001). The real costs of trade, referring to transport and other costs of doing business internationally, are important determinants of a country’s ability to fully participate in the world economy. While the importance of geography for transport costs in international trade has been widely established (since Hummels, 1998), often empirical studies in international trade neglect the national transportation system and focus more on geographical, comparative advantages and product characteristics[1].

GVC participation matters for economic development. Specifically, the ability of countries to prosper depends on their participation in the global economy and their role in GVCs (Gereffi and Lee, 2012). For this, the changing geography of global production is triggering changes in global distribution systems (Coe et al., 2004). The increased geographic spread induces an increasing importance of physical transportation of input and intermediary goods and services. This results in host country specific transaction costs moderated by the country specific transportation capabilities. Accordingly, infrastructure is quantitatively important for developing trade relations, with relevant policy implications for investment in infrastructure (Limao and Venables, 2001) requiring efficient logistics for complex production processes that span across several borders (Blyde, 2014).

Remoteness and poor transport and communications infrastructure isolate countries and inhibiting their participation in global production networks. Similarly, access to good quality ports, roads, railways and airports can play a key role in GVCs integration. The stable supply of transportation network may be crucial when many nodes of the chain depend on each other for timely and reliable delivery of inputs (Kowalski et al., 2015)[2].

Infrastructure development should rank at the top of the economic development agenda. Several studies have suggested that by lowering logistics costs, the stock and quality of a country's infrastructure can have a significant impact on its productivity and competitiveness (Amiti and Wei, 2009; Schwörer, 2013; Criscuolo and Timmis, 2017), economic growth and poverty reduction (Calderón, C., & Servén, 2014). Rodrigue (2006) argues that in the economic setting of GVC formation, intense global competition and diminishing profit margins, logistics offers opportunities to enhance the efficiency and productivity of production, with the high relevance of transport infrastructure for logistics costs (Limao and Venables, 2001). This holds especially true for developing countries for which transportation infrastructure is a key determinant of attractiveness and competitiveness (Percoco, 2014; Liu, 2015; Bensassi et al., 2015).

Investment in transport infrastructure can create positive externalities by stimulating demand for small-scale businesses, by attracting FDI, by decreasing import and export prices and by ensuring better consumer choices. Markets that are characterized by high transportation costs result in lower competition and higher costs of living. The differences in time and costs is explained by the quality of transportation infrastructure, standardization in inland shipment, and by the governance and security environment (Memedovic et al., 2008). Redding and Venables (2002) estimate that more than 70 per cent of the variation in per capita income across countries could be explained by the geography of market and suppliers, while better access to coastal/port areas alone could raise incomes by 20 per cent. While Limao and Venables (2001) estimate that poor infrastructure accounts for 40 percent of predicted transport costs for coastal

[1] Exceptions are given for example by Egger and Egger (2005), Halaszovich and Kirna (2019) and Kowalski et al. (2015).

[2] The empirical analysis draws on the different components of the World Economic Forum Global Competitiveness Index to include: (i) a composite indicator of physical transport infrastructure encompassing roads, air transport and ports; and (ii) an indicator of quality of electricity supply. In addition, data on broadband subscriptions from the International Telecommunications Union are used to proxy for the quality of information and communication technology of infrastructure.

countries and up to 60 percent for landlocked countries. These are serious obstacles for national firms wishing to participate more extensively in GVCs. In many developing countries, regional transport costs still explain a substantial share of the cost of delivering products to the market, becoming higher barriers to trade than border barriers (Bagai et al., 2004).

Despite factors determining a country's participation in a global supply chain and the influence of logistics infrastructure on trade facilitation are important from a policy making perspective (Bensassi et al.,2015; Martí et al., 2014, 2014), the literature in international trade mostly ignores the within-country aspect of transportation costs by using the geographic distance as a proxy for the latter. To the best of our knowledge, an approach to measure the integrated impact of distance and transportation system on the participation in the GVCs does not yet exist. While different approaches are used to investigate the impact of the transportation system of countries mostly on international trade and FDI, this work consider the value added in trade as suggested by the methodology developed in the international trade literature to address the issue of a country participation in GVCs, without overlooking the importance of institutional, cultural or economic differences between the countries involved in a transportation perspective.

Within supply chain, many production steps are carried out across different countries, with intermediate products travelling along the production chain between countries. It has been estimated that recently about 30 percent of global manufactured goods trade takes the form of trade in parts and components (Yeats, 2001). Despite its dimension, understanding international trade taking place in GVCs and its impact on national economies is still a work in progress (Escaith, 2014). It is no wonder, thus, that global value chains and the increasing fragmentation of production across borders have attracted considerable interest. The fragmentation of the production process across countries recently became the dominant model in industrial organization. Technical advantages in transportation and communications technology, as well as a serial institutional reform, have enable the fragmentation of the production process in different production stages located in different countries (Escaith, 2014). Mapping GVCs, identifying where value added is created, how much and by whom, what drives GVCs participation, and which benefits from it are the challenges faced in trade literature.

Recent studies have investigated the importance of transportation system and logistic in enhancing GVCs participation. It is well known that the development of transport infrastructure significantly lowers transport costs and makes feasible to spatially separate production and consumption. The transportation and communication technology revolution has redefined the function of time and distance (Gereffi and Luo, 2014) and improving infrastructure is a necessary condition for reaping the benefit of the participation in the global value chains to upgrade the economic structure (Ravenhill, 2014). A clear relationship come out between better logistics performance and deeper involvement in GVCs, using the World Bank's Logistics Performance Indicator (Dollar et al., 2017). According to World Economic Forum (2014), well-developed infrastructure not only reduces the distance between regions but also integrates national markets and connects them to other economies. The transportation, distribution and logistics approach is concerned with the value-added activities related to the flows supporting GVCs, from modes, terminals and the vast array of activities linked with freight distribution (Rodrigue, J. P., & Hesse, 2006). Thus, the role of transportation is considered more than a mere support to the mobility of freight within global value chains, but an integral part of the value generation process.

Nevertheless, investing in transport infrastructure to meet modern business needs has become a challenge for both developed and developing countries. Therefore, to bring countries further into the trading system of intermediate goods and services, it is important to understand the role of an efficient transportation system in moderating the effect of different between-country distances.

This work aims to contribute to a better understanding of the relationship between trade integration and transportation system across both high income and emerging countries. Starting from the assumption that trade between two countries is conditional to several characteristics of the countries involved that can either enhance or hinder bilateral business activities (Zwinkels & Beugelsdijk, 2010), we assess the host country's transport infrastructure network implications on two distinct measures of GVCs integration identified in the recent literature (Hummels, 2001; Koopman et al., 2014; OECD and World Bank, 2014; Taglioni and Winkler, 2016; Wang et al., 2017): GVC integration as buyer of foreign intermediate inputs (or, 'backward integration') and GVC integration as seller of intermediates to foreign exporters (or, 'forward integration').

A first in the literature to our knowledge, this paper assesses the determinants of GVCs participation in an augmented trade gravity framework. More specifically, we regress the FVA (backward integration) and DVX (forward integration) on typical gravity variables, such as trading nations' physical distance, gross domestic product (GDP) distance, institutional and cultural distance, as well as on indicators of between vertically integrated trading partners and a set of national transport infrastructure variables of the host country.

3. Methodology and data

3.1. Measures of GVCs integration

The research questions require the definition of measures for integration in GVCs. Measuring trade by value added, unlike sectors' contribution to GDP rather than by gross flows measures, provides an aggregative view of the importance of global supply chains (Pomfret and Sourdin, 2018). Moreover, as noted in Haltmeier (2015), Hummels et al. (2001) and Chen et. al. (2005), previous measures for GVCs – for example, imported input shares of gross output, total inputs, or exports – do not accurately characterize the extent of a country's involvement in such chains. This is because such measures are unable to assess the extent to which imported intermediates are used in a country's exports as opposed to domestic production.

Over the past years several institutions have assembled synthetic global input-output tables that describe the flow of intermediate and final goods across sectors and economies. The World Input-Output Database (WIOD)[3], which provides world input-

[3] The WIOD of the WTO provides world input-output tables for each year since 2000 covering 43 countries, including all 28 countries of the European Union and 15 other major economies (see Table 1). These 43 countries represent more than 85 percent of world GDP. It contains data for 56 industries covering the overall economy, including agriculture, mining, construction, utilities, manufacturing and services industries. The tables have been constructed by combining national input-output tables with bilateral

output tables (WIOT) in current prices, denoted in millions of dollars, is used following Timmer et al. (2013), Baldwin and Lopez-Gonzalez (2015) and Costinot and Rodríguez-Clare (2014). The 2016 release of the WIOD provides global input-output tables at annual frequency and covers 28 EU countries and 15 other major countries in the world and 56 sectors for the period from 2000 to 2014.

Therefore, the approach to measuring GVC participation based on IO tables is used. Hummels et al. (2001) first proposed a measure based on the share of vertical specialization (VS) or the import content of exports by using single-nation IO tables. In response to the limitations of the VS measure, international IO tables, which consist of detailed information on both inter-country and inter-industry linkages, have been used to measure GVCs in recent years. Studies taking this approach include Johnson and Noguera (2012), Stehrer (2012), Timmer et al. (2014) and Koopman et al. (2014). Moreover, Koopman et al. (2014) provides a unified mathematical framework for completely decomposing gross exports into its various components, including exported value added, returning domestic value-added, foreign value-added, and other additional items that may be double counted.

Specifically, for the main explanatory variables, countries' integration in GVCs, two measures are used. The first measure refers to the concept of foreign value added in trade (FVA) and the second one to the domestic value added in trade (DVX), both first developed by Hummels et al. (2001) and extended by Koopman et al. (2014). The foreign value added in trade (FVA) is a measure of vertical specialisation from the import perspective and it is an indicator for a *country's backward production integration*, given that it measures the value added of imported intermediate inputs that are used to generate export flows. Accordingly, this foreign value added is expressed as a percentage of the value added supplied by each industry that ends up being exported by a country[4]. Similarly, the domestic value added in trade (DVX) is a measure of vertical specialisation from the export perspective called *forward participation*, as it measures the value added of exports of intermediate goods and services that are used as inputs for the production of exports of other countries.

The measures for *backward production integration* (FVA) and *forward production integration* (DVX) can be added up to get an indicator for a country's GVC participation. If FVA and DVX are expressed as percent of exports, then the formula for GVC participation is as follows (Koopman et al., 2014):

$$GVC_{Partecipation} = \frac{FVA + DVX}{Gross\ Exports} \tag{1}$$

The larger the ratio, the greater the intensity of involvement of a specific country in GVCs.

The calculation of the FVAT and DVX require international input-output tables to trace back the value-added contents in gross exports to its ultimate source, which are obtained from the World Input-Output Database (WIOD). Following the exposition of

international trade data, following the conventions of the System of National Accounts. For detailed information about the WIOD, see Timmer et al. (2014).

[4] This is the reason why the calculation of the FVA was performed using the diagonalized value added coefficients and export vectors since this allows to single out the individual value-added contributions of each single partner country and industry.

Stehrer (2012) and Koopman et al. (2014), to calculate the foreign (and domestic) value added in trade for any country r three components are needed: the value added requirements per unit of gross output, $\boldsymbol{v_{ri}}$; the Leontief inverse of the global input-output matrix, $\boldsymbol{L}$; and the export vector, $\boldsymbol{x_{ri}}$. Both vectors, as well as the Leontief inverse matrix, have an industry dimension i.

First, the value-added coefficient of country r is defined as:

$$v_{ri} = \frac{value\ added_{ri}}{gross\ output_{ri}} \tag{2}$$

Each element of $\boldsymbol{v_{ri}}$ shows the share of direct value added in gross output for an industry i of a country r. The diagonal matrix $\boldsymbol{diag(v)_{ri}}$ of dimension 2408 (43 countries x 56 industries) is constructed which has the value added coefficients of country r as well as the value added coefficients of its trading partners.

The second element is the Leontief inverse of the global input-output matrix $\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-\boldsymbol{1}}$, where $\boldsymbol{A}$ denotes the technical coefficient matrix (Leontief, 1936). Each column in the WIOT table represents the required inputs from other industries (including imports and direct value-added) to produce the given amount of the product represented by that column. After normalization, the technical coefficient matrix represents the amount and type of intermediate inputs needed in the production of one unit of gross output. Using these coefficients, the gross output in all domestic stages of production that is needed to produce one unit of final products can be estimated via the so-called Leontief inverse. The coefficient $l_{r,r}$ indicates country r's input requirement from itself in order to produce one unit of output. Likewise, the coefficient $l_{n,r}$, for $n \neq r$, indicates country r's input requirement supplied by country n for country r to produce one unit of output.

In the WIOTs the coefficient matrix $\boldsymbol{A}$ (and also the Leontief inverse) is of dimension 2408 × 2408 which contains the technological input coefficients of country *r* in the diagonal elements and the technological input coefficients of country *r's* imports (from a column perspective) and exports (from a row perspective) in the off-diagonal elements.

Finally, the country r's trade vector $\boldsymbol{x_{ri}}$ is required. For mathematical calculation purpose, the diagonal matrix of dimension 2408, $\boldsymbol{diag(x)_{ri}}$, is constructed based on country r's export vector. In the trade vector, each element represents country r's exports to all its trading partners for each industry i. Hereafter, to facilitate the exposition the industry index has been omitted.

Using the three elements, the value added in trade matrix ($\boldsymbol{VAT_r}$) of dimension 2408 x 2408 can be calculated as follow:

$$\boldsymbol{VAT_r} = \boldsymbol{diag(v)_r} \cdot \boldsymbol{L} \cdot \boldsymbol{diag(x)_r}$$

$$= \begin{bmatrix} v_1 & 0 & \cdots & 0 \\ 0 & v_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & v_r \end{bmatrix} \begin{bmatrix} l_{1,1} & l_{1,2} & \cdots & l_{1,r} \\ l_{2,1} & l_{2,2} & \dots & l_{2,r} \\ \vdots & \vdots & \ddots & \vdots \\ l_{r,1} & l_{r,2} & \cdots & l_{r,r} \end{bmatrix} \begin{bmatrix} x_1 & 0 & \cdots & 0 \\ 0 & x_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & x_r \end{bmatrix}$$

$$= \begin{bmatrix} v_1 l_{1,1} x_1 & v_1 l_{1,2} x_2 & \cdots & v_1 l_{1,r} x_r \\ v_2 l_{2,1} x_1 & v_2 l_{2,2} x_2 & \dots & v_2 l_{2,r} x_r \\ \vdots & \vdots & \ddots & \vdots \\ v_r l_{r,1} x_1 & v_n l_{r,2} x_2 & \cdots & v_n l_{r,r} x_r \end{bmatrix} \tag{3}$$

The matrix in equation (3) shows the estimates of industrial value added of intermediate inputs that ends up in exports. Each element in the matrix represents the value added from a source industry directly or indirectly used in the production of intermediate inputs exported. In the matrix, walking along the row yields the distribution of value added created from an industry of country r used across all industries of all countries in the sample. Therefore, summing up the i-th row of the matrix, we obtain the total value added exported created by production factors employed in the i-th industry. In other words, it equals the total value added exported of the i-th industry of country r. At the same time, in the same matrix, a column yields the contributions of value added in intermediate inputs from all industries of all countries in the sample in order to generate exports flows by a specific industry of a country r[5]. Specifically, it contains the amount of value added embodied in country r's exports originating from country r itself and the foreign value added embodied in country r's exports originated by country partners. Since we are not interested in the first terms, for this reason, the diagonal values of the $\boldsymbol{VAT_r}$ matrix are not taken into consideration[6]. The total foreign value added in trade (and domestic value added in trade) for each country pair is obtained by summing up over all FVATs (and DVXs) from all industries between two countries.

Considering the backward and forward integration indicators discussed above, the independent variables considered are: (a) backward links expressed in value terms (the foreign value added embodied in gross exports for each country pair - FVATCP); (b) forward links expressed in value terms (the domestic value added destined for processing and exports by each country partner DVXCP)[7]. Both variables are calculated using information from the World Input-Output Tables from WIOD which interest the period of analysis from 2000 to 2014.

3.2. The gravity model for international trade

The value chains are becoming increasingly global (Los et al., 2015) and world trade still remains exposed to gravity (Escaith and Miroudot, 2015). More generally, trade volumes depend on an entire network structure of trade connections (Basher and Westbrock, 2014).

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[5] This is the reason why the calculation of the VAT was performed using the diagonalized value added coefficients and export vectors since this allows to single out the individual value-added contributions of each single partner country and industry.

[6] Alternatively, FVATCP can be retrieved directly by omitting country r's own value-added coefficients in the $\boldsymbol{diag(v)_{ri}}$ matrix.

[7] The foreign value added in trade of each country pair (FVATCP) is calculated as the value added generated by foreign industries of a country partner irrespective of which industry is responsible for the export of this value added. The same also applies to the domestic value added in trade of each country pair (DVXCP).

Since the gravity equation was introduced by Tinbergen in 1962, the gravity model has always been around in policy cycle, because it has proven to be among the "most stable and robust empirical regularities in economics" over time and across different samples of countries and methodologies (Chaney, 2013).

Although qualitative or microdata-based product or industry case studies provide in-depth information on the configuration and characteristics of a specific supply chain, they do not offer a comprehensive picture at the macro level of an economy's participation in global production chains (Koopman et al., 2014). Because of the "double-counting" problem in conventional gross trade statistics, mainly caused by intermediate goods crossing borders multiple times, approaches based on conventional trade data risk overstating domestic value-added content of exports (Johnson and Noguera 2012). Using inter-country input-output tables that link production processes within and across countries has been recognized as the most feasible, consistent, and comprehensive approach to measure trade in value-added terms globally (Jones et al. 2014). We follow the established literature and use aggregated data in our analysis based on the World I-O Tables from the WTO to test our hypothesis.

Gravity models are often used in applied international trade literature to investigate international trade flows between countries. These models are based on the assumption that trade between two countries is conditional on several characteristics of the countries involved that can either enhance or hinder bilateral business activities (Zwinkels and Beugelsdijk, 2010). To explore the main determinants for a country's involvement in GVCs, we estimated a gravity model, where the traditional set-up was modified to include modern notions of proximity, as described afterwards.

For the estimations we use augmented gravity equations in the multiplicative form following Santos Silva and Tenreyro (2006):

$$\boldsymbol{Y}_{ij,t} = \beta_0{}' \times \boldsymbol{X}_{ij,t}{}^{\beta_1{}'} \times \boldsymbol{D}_{ij,t}{}^{\beta_2{}'} \times T_{i,t}{}^{\beta_3} \times \varepsilon_{ij,t} \tag{4}$$

where $Y_{ij,t}$ represents the two measures of GVCs participation based on country-pair ij in year t. The matrix $\boldsymbol{X}_{ij,t}$ includes all distance measures and the matrix $\boldsymbol{D}_{ij,t}$ contains the dummy measures we use to control for common border and other trade related policies, also year and country effect, in addition to a set of national transportation system variables of country of origin i involved in the GVCs are used denoted as $T_{i,t}$ and the standard error term $\varepsilon_{ij,t}$.

Inasmuch as the independent variables follow a Poisson distribution (Figure 1), the Pseudo Poisson Maximum Likelihood (PPML) estimator is used.

Because of the presence of heteroskedasticity, estimates of the log-linear form of the gravity equation are biased and violate the condition of consistency of OLS, that this may lead to prefer the Poisson specification of the trade gravity model (Santos Silva and Tenreyro, 2006, 2011; Arvis and Shepherd, 2013; Fally, 2015; Correia et al., 2019). In addition, zero trade flows and small values are relatively common in the bilateral trade matrix even using aggregate trade data (Helpman et al., 2008). It raises to the "zero trade flows" issue, which introduces obvious problems in the log-linear form of the gravity equation. Several authors argue that gravity type models should be estimated in multiplicative form and recommend the Poisson Pseudo-Maximum Likelihood (PPML) estimator to deal with the problem of heteroskedasticity and zeros in the trade matrix, also to take advantage of the information contained in the zero trade flows and to achieve unbiased and consistent estimates.

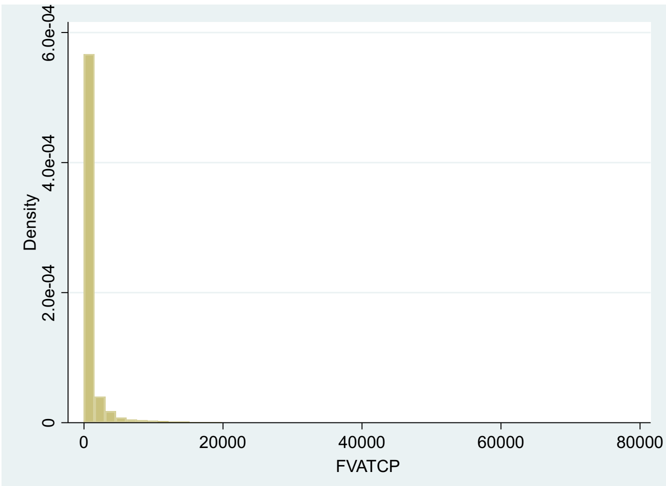

Figure 1: Density distribution histogram of the independent variable.

Given the crucial role of bilateral trade costs for international trade analysis, as recommended, country-pair fixed effects are used by introducing country pair dummies, which successfully account for endogeneity of trade policy variables.

Accordingly, we estimate the gravity equation using a Poisson pseudo-maximum-likelihood estimator, following Silva and Tenreyro (2006). More precisely, the Stata command *ppmlhdfe* developed by Correia et al. (2019) was employed, which allows handling in a computationally efficient way the large number of fixed effects in the gravity equation.

3.3. Independent variables

In the following we describe the nature and sources of the explanatory variables used in this study to estimate the gravity dependence of the participation in GVCs and the impact of the national transportation system in enhance countries involvement in such GVCs.

First, we computed the bilateral distances.

Geographic distance is mostly described by the spatial distance between two locations and the ease of accessibility, as land or water connections. A direct implication of increasing geographic distance is an increase of transportation costs (Daniels & von der Ruhr, 2014; Memedovic et al., 2008). Trade costs, which are often proxied using measures of distance, are fundamental determinants of trade and only few firms exhibit productivity premia that allow facing the costs of selling in foreign markets (Melitz, 2003). We expect GVC trade to exhibit similar properties. In addition to this, geographic distance also increases perceived uncertainty and thereby results in costs of additional control mechanisms (Sachdev and Bello, 2014).

For geographic distance (dGEO), we used the distance between the capital cities of country pairs in kilometres according to CEPII database. This distance measure is calculated using the great circle formula based on the coordinates of the capital cities (Meyer & Zignago, 2011).

The institutional distance measure (dWGI) is based on the distance between the home and host country's World Governance Index (WGI) values. The WGI is an index that incorporates information on the institutional quality of over 200 countries since the year 1996. The information is based on over 30 individual data sources (World Bank, 2018). This information is aggregated in six individual governance indicators: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.

To measure the institutional distance between the bilateral country pairs in our sample, we calculated the Euclidean distance based on equation (5):

$$dWGI_{ij} = \sqrt{\sum_{k=1}^{6} (X_{ki} - X_{kj})^2} \tag{5}$$

where X_{ki} is the value of governance indicator k for country i and X_{kj} is the value of governance indicator k for country j.

For computing the cultural distance (dCULT) the Hofstede's data on national culture (Beugelsdijk et al., 2015) are used. According to Hofstede, the culture of a country can be measured on six dimensions (i.e. power distance, individualism, masculinity, uncertainty avoidance, long term orientation, and indulgence). The original approach by Kogut and Singh (1988) was limited to the first four cultural dimensions, as only these were available by that time. In this study, we follow the modified the formula proposed by Halaszovich and Kinra (2018) which includes all six dimensions:

$$dCULT_{ij} = \sum_{k=1}^{6} \left\{ \frac{(I_{ki} - I_{kj})^2}{V_k} \right\} / 6 \tag{6}$$

where I_{ki} is the value of the cultural dimension k for country i, I_{kj} is the value of the cultural dimension k for country j and V_k is the variance of the score per cultural dimension k.

Finally, economic distance is defined by different income levels, cost and quality of resources (natural, financial and human), and differences in the stock of knowledge (Ghemawat, 2001). Activities motivated by resource and efficiency seeking (e.g. low-wage production) can benefit from a weaker economic level in the origin of trade flows country (Dunning & Lundan, 2008). In fact, the lower level of economic development in the origin country is usually required to allow for lower wages and access to a larger pool of mostly un- or semi-skilled workforce.

Economic distance (dECO) is measured as Euclidean distance of the GDP per capita in constant US dollars of the country pairs. The GDP per capita data was taken directly from the World Bank database.

$$dECO_{ij} = \sqrt{(GDP_i - GDP_j)^2} \tag{7}$$

where GDP_i is the the GDP per capita of country i and GDP_j is the GDP per capita of country j.

The measures of institutional distance and economic distance are dynamic over time while cultural and geographical distances are static. Table 1 provides an overview of all countries in the sample and summarize the average values of the four distance measures used in this study.

The transportation, distribution and logistics approach is concerned with the value-added activities related to the flows supporting global production network, from modes, terminals and the vast array of activities linked with freight distribution. Thus, the role of transportation is considered more than a mere support to the mobility of freight within global commodity chains, but an integral part of the value generation process of a country (Rodrigue, and Hesse, 2006). Besides, infrastructure is quantitatively important in determining transport costs and it depends both on countries' geography and on their level of infrastructure (Limao & Venables, 2001). Therefore, not only the between countries transportation costs matter, but also the quality of the transportation system of the country of origin.

To measure the availability and quality of national transportation systems of countries in our sample, we used data from the World Economic Forum (WEF, Global Competitiveness Report) for four main transport modes – roads, rails, ports and airports – which covered more than 130 countries [8]. Despite other scholars largely use the Logistic performance index from the World Bank, as both an aggregated index or in its more disaggregated measures (e.i. Saslavsky and Shepherd, 2012; Martí et al., 2014; Halaszovich and Kinra, 2018), relying always in severe multicollinearity and with limitation of the time span and number of countries covered by the data abovementioned[9]. To avoid some of these issues, to assess the quality of the national transportation system data from the WEF are used, as in Kowalski et al. (2015). Also, multicollinearity troubles among the four transport modes value scores persist. To address the issue, each of the quality of the transportation mode variables are regressed on principal components after computing the factor analysis for the four variables used in this work. Considering the idiosyncratic part of each measure, it is possible to reduce significantly the correlation among the variables and to refine the measures from factors that may generate multicollinearity.[10] We included the measures of national transportation systems to test for the direct effects of these systems on our GVCs measures by introducing interaction-terms.

[8] The survey responses are: How would you assess the quality of overall infrastructure; roads; rails; air transport; ports in your country? [1 = extremely underdeveloped-among the worst in the world; 7 = extensive and efficient-among the best in the world). For a better illustration of the transportation variables the score values have been reported on a 0 to 100 scale. The data are updated annually and available for the period 2007-2018, except for rail infrastructure measure which covers the period 2009-2018.

[9] Referring to the period covered by the WIOD, the Logistic performance index is available only for the years 2007, 2010, 2012 and 2014 among those which interest this study.

[10] Similar approaches are largely used in the econometric literature, as for example it is used by Di Giacinto et al. (2012) to get a decomposition of the public capital in transport infrastructures into common and idiosyncratic components. All the regression was estimated including both the common factor component and the idiosyncratic part. Since the common factor does not shows explanatory power and also it doesn't affect the results, it is not included in the final estimates.

Table 1: Overview of countries and distance measures.

Developing Courtiers		dGEO	Average dWGI	dCULT	Average dECO
Sub-Region	*Country*				
Europe	Bulgaria	3344	2.38	1.82	25183
	Cyprus	4040	1.66	-	18834
	Czech Republic	3048	1.74	1.19	19180
	Estonia	3306	1.65	1.79	20108
	Greece	3629	1.9	1.58	18683
	Croatia	3136	2.14	1.41	20535
	Hungary	3096	1.71	1.88	20725
	Latvia	3208	1.83	2.10	21515
	Lithuania	3179	1.78	1.92	21443
	Malta	3750	1.79	1.47	18869
	Poland	3084	1.81	1.62	21460
	Romania	3327	2.64	2.15	24026
	Russia	3577	4.12	2.43	22412
	Slovakia	3065	1.85	3.00	20128
	Slovenia	3132	1.69	1.80	18709
	Turkey	3739	2.87	1.30	22008
Pacific	China	7322	3.95	2.79	27206
	India	6276	3.28	1.67	29492
	Indonesia	10170	3.86	1.95	27936
	Korea Republic	7882	1.74	2.40	18957
	Taiwan	8528	1.65	1.95	-
America	Brazil	10280	2.61	1.32	21953
	Mexico	9961	2.85	3.14	22716
Developed Countries					
Sub-Region	*Country*				
Europe	Austria	3063	2.05	2.12	22573
	Belgium	3229	1.78	1.69	21502
	Denmark	3136	2.51	3.12	31741
	Finland	3346	2.59	1.57	22342
	France	3332	1.74	1.28	20599
	Germany	3066	1.92	1.54	20803
	Ireland	3640	1.94	2.42	25178
	Italy	3368	1.85	1.42	19759
	Luxemburg	3190	2.24	1.12	71580
	Netherlands	3216	2.22	2.00	24849
	Norway	3332	2.27	2.13	57388
	Portugal	4281	1.68	2.12	18743
	Spain	3940	1.84	1.15	18913
	Sweden	3259	2.34	2.85	25355
	Switzerland	3224	2.28	1.65	43747
	United Kingdom	3390	2.04	2.26	20300
Pacific	Australia	14411	2.06	2.47	25130
	Japan	8541	1.73	2.25	21911
America	United States	7585	1.87	2.34	23834
	Canada	7108	2.07	1.82	23336

In addition to these measures, we included dummy variables to measure if two countries share a common border or are part of a free trade agreement (FTA).

Table 2 shows the summary statistics of our dependent variables, distance and transportation measures.

Table 2. Summary statistics

	Obs.	*Mean*	*St. dev.*	*Min*	*Max*	*Units of measurement*
Dependent variables						
FVACP	27090	1024	3138	0	66894	Constant US $
DVXCP	27090	1024	3138	0	66894	Constant US $
Independent variables						
For country-pair						
dGEO	27090	4891	4390	60	18524	Kilometres
dWGI	27090	2.25	1.42	0.10	7.21	Equation (4)
dCULT	25830	2.00	1.22	0.03	6.69	Equation (5)
dECO	25830	25404	20826	1.14	110795	Constant US $
Border	27090	0.06	0.24	0	1	0/1
FTA	27606	0.51	0.50	0	1	0/1
Pop origin	27735	99.73	260.46	0.38	1364.27	Total in million
For country of origin						
Road	336	66.66	18.54	27.25	96.01	0-100
Rails	240	62.08	17.39	24.79	97.21	0-100
Ports	336	68.95	14.34	35.97	97.27	0-100
Airports	336	74.47	12.94	43.47	95.80	0-100

4. Econometric results

To test our hypotheses, we first estimate a baseline model containing the different distance measures, as well as control variables related to information on FTAs and common border (Table 3 and Table 4). All the models have been estimated using the full sample, a subsample of emerging countries and all their trading partners and a sub-sample of only developed countries and all their trading partner to differentiate the participation in GVCs according to the level of development. As additional control measures, in this study, individual country effects are considered as trading capabilities of the country involved in GVCs. Also, we control for time fixed effects. These fixed effects are considered due to the omitted variables specific to country and time effects. The former can be related to trade policy measures including tariff and non-tariff barriers and export driving or impeding other 'environmental' variables in the country of origin. The latter includes business cycle effects. These are not random but deterministically associated with certain historical, political, geographical and other factors (Egger, 2000).

Modelling the gravity equation explicitly, in its multiplicative form, allows moreover the estimates to be interpreted as trade elasticities. This enables a direct comparison of the trade effect caused by distances, transportation systems and other control variables.

The results of our base model (Table 3 and Table 4) on distances are mostly in line with our expectations. However, since the results in terms of both distances and transportation systems on direct measures of GVCs participation are novel, they provide some interesting insights.

Many studies using gravity models confirm that geographical distance matters greatly for international trade (Disdier and Head, 2008), and one of the few well-established empirical results is the negative relationship between geographical distance and bilateral trade. Also, Cheng et al., (2015) and Stöllinger and Stehrer (2015) find that geographic distance between trading partners acts as a barrier to the integration in international production networks. Moreover, the geographic distance seems to matter more for emerging countries in an import perspective compared to developed economies. Nevertheless, the coefficient from a backward production integration perspective shows a larger magnitude for both groups of countries.

Table 3: Econometric results of the baseline model (all countries).

	FVT flows		*DVX flows*	
	Coef.		*Coef.*	
dGEO	-0.000157	***	-0.000017	***
	(0.000029)		(0.0000033)	
dWGI	0.1724743	***	0.093405	***
	(0.057107)		(0.049389)	
dCULT	-0.0931822		-0.067978	
	(0.063561)		(0.051164)	
dECO	-0.000023	***	-0.000169	***
	(0.000005)		(0.000033)	
Border	1.305285	***	0.975661	***
	(0.161804)		(0.127766)	
Pop origin	0.0022812	**	0.005776	**
	(0.001108)		(0.001472)	
FTA	-0.908040	***	0.081690	***
	(0.228557)		(0.181511)	
Constant	8.456723	***	7.415881	***
	(0.366006)		(0.369238)	
Year FE	Yes		Yes	
Regional FE	Yes		Yes	
Obs.	24600		24600	
Clusters country pair	1640		1640	
Pseudo R2	0.5344		0.6500	
Log pseudolikelihood	-18678850.7		-14040547.6	
Wald Chi2	208.71	***	280.71	***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

In the international trade literature, the effect of institutional distance is heterogeneous. Even a deterring effect of poor institutional on trade and FDI prevail[11], the estimates provide a positive relationship of the institutional distance independently of the level of development of the country involved in GVCs and mostly in an import perspective of the participation measure (foreign value added in trade flows). The positive effect of political institutional distance may be explained with firms arranging business in less than legitimate ways with the help of politics on one or the other side (Kuncic, 2013).

[11] For example, Acemoglu et al. (2005), Kaufmann and Kraay (2002), Rodrik et al. (2004), Wei (2000), Daude and Stein (2007). Those studies mostly consider developed countries.

Moreover, investors might be able to mitigate the risk associated with operating in risky environment or be prepared to invest in countries that are usually avoided by other investors due to ethical reasons (Buckley et al., 2007) and, because incentives to invest differ across investors, that countries with bad institutions do not necessarily have to improve their quality in order to attract investors (Darby et al., 2009; Cuervo-Cazurra, 2006).

Instead, cultural distance shows a negative but not significative coefficient when the full sample is considered, while it becomes statistically significative and negative only for developed economies both from an import and an export involvement perspective in GVCs. Despite the literature suggests that trade between countries decreases with cultural distance (Linders et al. 2005; Lankhuizen et al. 2011), our results suggest that this effect seems to be more relevant when considering foreign and domestic value added in trade of intermediaries that involve developed countries.

The economic distance between countries reflect their differences regarding factor costs (such as labor wage rate) and technological capabilities. Two conflicting effects of this variable on trade are identified in the international trade literature. When the trading countries have very different per capita incomes, lower economic distance might foster trade, on the basis of the Linder (1961) model[12]. On the other hand, higher economic distance might foster inter-industry trade (countries import and export different goods) if we consider the Heckscher-Ohlin (H-O) model[13]. The effect of economic distance on the two GVCs measures shows negative coefficients suggesting that the so-called Linder effect dominated the Heckscher–Ohlin effect. Moreover, the coefficients show large magnitude in an export perspective of GVCs trade flows of intermediaries. Only in the emerging economies subsample *dECO* is not statistically significant from an import perspective involvement in GVCs.

Furthermore, adjacent countries trade substantially more foreign and domestic value added in intermediate inputs than non-contiguous countries[14], confirming the importance of proximity for participating in the global production network, while the presence of free trade agreements between two countries seems to have a controversial effect on GVCs participation. We believe that the negative relationship can be interpreted more as a global rather than a regional feature of production networks, thus overcoming the barriers of trade agreements.

We also control for population of the country of origin involved in GVCs as a proxy for market size. It shows positive and significative coefficients. Particularly, the market size seems to positively affect export and negatively affect import GVC-related trade flows of emerging and developed countries respectively. A similar negative coefficient in the case of both backward and forward integration implying that the smaller the population the larger the participation in GVCs was found by Kowalsky et al. (2015) considering a large panel dataset of 57 countries. Following the results, we can assess that this effect is true when considering developed countries as buyers (import

[12] According to this effect, countries tend to increase their bilateral trade in similar products when their per capita incomes are more similar. Therefore, is expected trade to be intra-industry (countries should both export and import the same goods) when per capita incomes converge.

[13] H-O centers on expected trade patterns when countries have different factor endowments, but similar tastes. Per capita income differences can represent inter-country differences in factor scarcity. In this approach, there is a positive relationship between the share of vertical intra-industry trade and differences in per capita income, as long as differences in GDP per capita are proxies for differences in relative wage.

[14] The percentage trade impact for dummy variable j can be computed as follows: $(e^{\beta j} - 1) \times 100\%$.

perspective), but not for emerging economies where the larger the population the larger the involvement in GVCs as suppliers (export perspective) but not as buyers (import perspective) which shows a negative but not statistically significant coefficient.

Table 4: Econometric results of the baseline model (subsamples of emerging and developed economies).

	Emerging economies				*Developed economies*			
	FVT flows		*DVX flows*		*FVT flows*		*DVX flows*	
	Coef.		Coef.		Coef.		Coef.	
dGEO	-0.000210	***	-0.000007		-0.000170	***	-0.000034	***
	(0.000056)		(0.000004)		(0.000022)		(0.000005)	
dWGI	0.215262	***	0.182944	*	0.228284	***	0.074633	
	(0.070839)		(0.095302)		(0.086029)		(0.066876)	
dCULT	0.016887		-0.074858		-0.174926	**	-0.147526	**
	(0.091225)		(0.083079)		(0.069881)		(0.059401)	
dECO	-0.000001		-0.000178	***	-0.000047	***	-0.000225	***
	(0.000004)		(0.000047)		(0.000007)		(0.000043)	
Border	1.387256	***	0.540344	**	1.207273	***	1.013842	***
	(0.254560)		(0.246635)		(0.165297)		(0.126103)	
Pop origin	-0.001362		0.003328	***	-0.056217	***	-0.005199	
	(0.001302)		(0.001197)		(0.017527)		(0.011859)	
FTA	-0.692114	***	0.486706	**	-1.281115	***	-0.480381	**
	(0.226617)		(0.236989)		(0.275946)		(0.228075)	
Constant	8.265673	***	7.134726	***	12.192330	***	9.583113	***
	(0.721840)		(0.606962)		(0.744352)		(0.671164)	
Year FE	Yes		Yes		Yes		Yes	
Regional FE	Yes		Yes		Yes		Yes	
Obs.	13,200		13,200		11,400		11,400	
Country pair clusters	880		880		760		760	
Pseudo R2	0.5436		0.5436		0.5729		0.5729	
Log pseudolikelihood	-6809627		-6809627		-9642471		-9642471	
Wald Chi2	94.28	***	214.21	***	228.39	***	228.39	***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

Finally, we control for the time trend as we think such a trend might be important because they capture the influence of aggregate trends and show all statistically significant positive coefficients. We take the time dummies as indicators of the extent of "globalization", which we define as the purported common trend towards greater real GVC-related trade volumes, independent of the sizes of the economies. In addition, to control for regional effects, countries of origin dummies are included to consider any additional incentives at country level that foster participation on GVCs provided by a country's government to after assessing the impact of the national transportation system.

In the next models, we included the different measures of national transportation systems to respond to one of the general research questions, that is whether the components of the national transportation systems stimulate GVC related trade volumes in addition to institutional, cultural, economic and geographic distances acting like berries of involvement in global production networks considering firstly the all sample (Table 5) and then the subsamples of emerging and developed economies (Table 6).

Table 5: Econometric results with national transportation system variables (all countries).

	FVT flows		*DVX flows*	
	Coef.		Coef.	
dGEO	-0.0000216	***	-0.0001737	***
	(0.000005)		(0.000034)	
dWGI	0.1795923	***	0.093434	*
	(0.058814)		(0.050743)	
dCULT	-0.0723601		-0.061927	
	(0.063115)		(0.052556)	
dECO	-0.000156	***	-0.000015	***
	(0.000027)		(0.000003)	
Border	1.307663	***	0.950765	***
	(0.156476)		(0.133542)	
Pop origin	-0.0021123		0.005997	***
	(0.001560)		(0.001433)	
FTA	-1.078083	***	-0.008170	
	(0.226618)		(0.194515)	
Inland transport	1.261882	*	-0.650353	
	(0.717770)		(0.733107)	
Maritime transport	1.142532	**	-0.516639	
	(0.506525)		(0.504560)	
Air transport	0.7473384	**	-0.518408	
	(0.379604)		(0.394317)	
Constant	9.347928	***	7.470615	***
	(0.404861)		(0.415228)	
Year FE	Yes		Yes	
Regional FE	Yes		Yes	
Obs.	9600		9600	
Country pair clusters	1600		1600	
Pseudo R2	0.5134		0.6142	
Log pseudolikelihood	-9516327		-7519604.7	
Wald Chi2	224.38	***	267.13	***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

Our findings provide different nuanced answer to this question. If we look to the whole sample all transportation systems are significant and positive for GVC-related to imports that embed foreign value-added re-exported in other countries. We found negative but no significant effect of the quality of all infrastructures on GVC-related to export of domestic value-added that are re-exported in other countries' exports. There results differ from those that previously have assess the impact of different transportation modes on trade flows like import and export volumes, where the impact of the national transportation system seems to matter more for export activities (Francois and Manchin, 2013). These results also allow us to further confirm that the two phenomena, that of international trade in the broad sense (import and export flows) and participation in GVCs, are to be considered not one the consequence of the other, especially when considering the impact of the national transport system. We think that this is due to an exceed relevance of country-specific structural and policy characteristics that count more for the extent of the backward GVCs integration despite of the forward engagement. The latter likely reflects the fact that this type of engagement captures the supply side of value chains and covers a diverse range of idiosyncratically specialized countries such as those supplying natural resources (e.g. Russia or Australia), or high tech intermediate inputs (Germany and Japan) as well as specialized services (the United Kingdom and the United States) the determinants of which are likely to differ. In contrast, the backward engagement captures the demand side of value chains which is more closely linked to broad structural characteristics of countries such as the degree of industrialisation (OECD, 2014). Although, due to the lack of empirical studies on the relationship of GVCs and the national transportation system, we often rely on comparing results with those who consider international trade in a broader sense.

Table 6: Econometric results with national transportation system variables (subsamples of emerging and developed economies).

	Emerging economies				*Developed economies*			
	FVT flows		*DVX flows*		*FVT flows*		*DVX flows*	
	Coef.		Coef.		Coef.		Coef.	
dGEO	-0.000189	***	-0.000165	***	-0.000173	***	-0.000239	***
	(0.000052)		(0.000049)		(0.000024)		(0.000042)	
dWGI	0.234068	***	0.175943	*	0.246467	***	0.103744	
	(0.074161)		(0.096061)		(0.089370)		(0.069520)	
dCULT	0.031267		-0.076378		-0.169787	**	-0.145552	**
	(0.089584)		(0.079696)		(0.069816)		(0.061856)	
dECO	-0.000002		-0.000005		-0.000044	***	-0.000032	***
	(0.000004)		(0.000004)		(0.000007)		(0.000006)	
Border	1.455961	***	0.539355	**	1.188504	***	1.022609	***
	(0.244704)		(0.254013)		(0.161375)		(0.129491)	
Pop origin	-0.005656	***	0.005238	***	-0.009503		0.025979	*
	(0.001822)		(0.001588)		(0.017710)		(0.013892)	
FTA	-0.781106	***	0.363876		-1.440196	***	-0.520982	**
	(0.235277)		(0.262004)		(0.283803)		(0.237808)	
Inland transport	0.907649		1.703224	*	1.390083		-3.077623	***
	(0.641647)		(0.942245)		(1.074645)		(1.043836)	
Maritime transport	0.676335	**	0.988847		0.984758	*	-2.199013	***
	(0.337747)		(0.664417)		(0.567834)		(0.720141)	
Air transport	1.044655	**	0.719559		1.026489		-1.811492	***
	(0.476011)		(0.481239)		(0.736558)		(0.580265)	
Constant	9.986281	***	6.352293	***	10.438320	***	8.229254	*
	(0.810584)		(0.817823)		(0.892985)		(0.771635)	
Year FE	Yes		Yes		Yes		Yes	
Regional FE	Yes		Yes		Yes		Yes	
Obs.	5,040		5,040		4,560		4,560	
Country pair clusters	840		840		760		760	
Pseudo R2	0.5193		0.6463		0.5547		0.6398	
L. pseudolikelihood	-3632905		-3641950		-4869966		-3225180	
Wald Chi2	132.15	***	183.55	***	224.26	***	299.11	***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

When we look at the direct effect of transportation systems on the GVCs measures considering the different level of development of countries involved, dissimilar results emerge. The quality of maritime and air transportation system seems to be related more with the backward integration (from an export perspective) in emerging countries, which is also the first step to be engaged in a GVC production network, while the quality of the inland transportation system shows a low but positive significative coefficient for the forward production integration (from an export perspective). Moreover, only the quality and efficiency of the maritime transportation system in the subsample of developed countries involved in GVCs show a positive and significative coefficient from the demand side, while we found a reversed effect for all the transportation modes that show highly significative but negative coefficients from the supply side of value chains (domestic value added flows). We believe the negative relationship occurs since the backward integration is also a result, as mentioned above, of countries determinants which are likely to differ and not strictly related to quality of the transportation system. This result might need to be further investigated in future works.

The third and final set of estimates, extended model two with interaction terms of transport infrastructures (inland, sea and air transportation system) with geographic, institutional, economic and cultural distances separately to test for the ability of the transportation systems to reduce the cost of distances (Table 7 and Table 8). Abbreviated results of Table 7 are shown in the following, while the full one is reported in Appendix.

Our main hypothesis is that better developed national transportation systems reduce the negative influence of geographic distance mostly in terms of transportation costs. The results support this statement by showing that the overall national transportation system is quite relevant for the backward production integration in emerging economies in reducing the cost of trade. The interaction terms with the *dGeo* show positive and significant coefficients from an import perspective when considering the all sample. Hence, the quality and efficiency of inland, port and airport infrastructures are effective in lowering the costs of geographic distance when GVCs are concerned. Distinguishing according to the level of development, positive and significant coefficients are found only in the case of emerging economies. The national inland transportation system (the quality of road and rail network) reduces the negative effect of the geographical distance for both backward and forward integration and increases GVCs trade flows, while the quality of maritime and air transport are found to be significant when the emerging countries are involved mainly in the backward production integration or form an import perspective in GVCs participation.

Minor effects of the national transportation system on reducing some of the other distance dimension considered in the gravity equation are found to be relevant mostly for developed countries. Only statistically significant results are summarized in Table 8.

All the interactions of institutional distance (*dWGI*) and cultural distance (*dCULT*) with national transportation variables shows positive and significant coefficients for the developed countries subsample only for the backward production integration. In view of the national transportation systems in helping to overcome the negative effects of institutional and cultural distance in those countries, we believe these results are due to the fact that the countries involved in GVCs from an import perspective trade value added in intermediates mainly with other developed economies which represent the supply side of value chains towards these countries. From this point of view, institutional and cultural distances are particularly important and the improvement of the quality of transport infrastructures contributes to increase GVC flows from an import perspective when developed countries are involved.

Table 7: Econometric results of the effect of the national transportation system in moderating the geographic distance (all, emerging and developed economies).

	All economies		*Emerging economies*		*Developed economies*	
	FVT flows	*DVX flows*	*FVT flows*	*DVX flows*	*FVT flows*	*DVX flows*
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
[results are shortened]						
dGEO x Inland	0.0009 *	0.0005	0.0009 *	0.0008 *	0.0005	0.0002
	(0.0006)	(0.0005)	(0.0005)	(0.0004)	(0.0006)	(0.0006)
dGEO x Maritime	0.0007 *	0.0004	0.0007 *	0.0006	0.0004	0.0001
	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0005)
dGEO x Air	0.0005 *	0.0002	0.0005 *	0.0004	0.0003	0.0001
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Obs.	9600	9600	5,040	5,040	4560	4560
Country pair clusters	1600	1600	840	840	760	760
Pseudo R2	0.5176	0.6151	0.5239	0.6499	0.5561	0.6403
Log pseudolikelihood	-9435499	-7501197	-3597924	-3604808	-4854880	-3221278
Wald Chi2	251.85 ***	288.96 ***	156.4 ***	191.11 ***	249.28 ***	341.68 ***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

Table 8: Econometric results of some effects of the national transportation system in moderating different distances.

	Emerging economies		*Developed economies*		*Developed economies*	
	FVT flows		*FVT flows*		*FVT flows*	
	Coef.		Coef.		Coef.	
dGEO	-0.0002	***	-0.0002	***	-0.0002	***
	(0.0001)		(0.0000)		(0.0000)	
dWGI	0.2333	***	0.2490	***	0.2139	**
	(0.0736)		(0.0892)		(0.0895)	
dCULT	-0.0153		-0.1874	***	-0.1399	**
	(0.0851)		(0.0694)		(0.0686)	
dECO	0.0000		0.0000	***	0.0000	***
	(0.0000)		(0.0000)		(0.0000)	
Border	1.4539	***	1.1839	***	1.2128	***
	(0.2442)		(0.1603)		(0.1616)	
Pop origin	-0.0058	***	-0.0175		-0.0123	
	(0.0019)		(0.0181)		(0.0180)	
FTA	-0.7920	***	-1.4311	***	-1.4233	***
	(0.2342)		(0.2789)		(0.2815)	
Land transport	3.2976	*	-3.2126		-2.7749	
	(1.8549)		(2.3513)		(1.7911)	
Maritime transport	3.2277	**	-2.2960		-2.0397	
	(1.4083)		(1.6711)		(1.3000)	
Air transport	2.0582	**	-1.1223		-0.8811	
	(0.9941)		(1.2860)		(0.9056)	
dCULT x Inland	-1.2526		2.9215	**		
	(0.9946)		(1.4123)			
dCULT x Maritime	-1.1335	*	2.1389	**		
	(0.6884)		(1.0229)			
dCULT x Air	-0.7369		1.3222	*		
	(0.5482)		(0.7784)			
dWDI x Inland					2.1833	**
					(0.8874)	
dWDI x Maritime					1.5953	**
					(0.6460)	
dWDI x Air					0.9756	**
					(0.4627)	
Constant	10.0510	***	10.7836	***	10.5255	***
	(0.8209)		(0.9022)		(0.8999)	
Year FE	Yes		Yes		Yes	
Regional FE	Yes		Yes		Yes	
Obs.	5,040		4560		4560	
Country pair clusters	840		760		760	
Pseudo R2	0.5209		0.5614		0.5601	
Log pseudolikelihood	-3620872		-4796225		-4810547	
Wald Chi2	136.94	***	238.02	***	257.24	***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.

Instead, when emerging economies are involved in GVCs, a significant but negative effect was found between cultural distance and quality of maritime transportation, which seems to be not able to moderate the negative effect caused by cultural diversity.

According to our findings, economic distance therefore is the only distance dimension that cannot be influenced by national transportation systems at all.

5. Conclusions

This work has important policy implications, especially for emerging economies, where GVCs participation is a priority on the policy agenda (Rao and Dhar, 2018). GVCs involvement offers opportunities for development and growth that potentially allow these countries to improve their economic development.

Investigating the determinants of the participation in the global production network for both emerging and developed economies, we provide interesting empirical results. The gravity model implemented confirm that the participation on GVCs is exposed to gravity. In addition to the institutional environment, the level of economic development and the geographic location, also the quality of national transportation systems is determinant of the ability of countries to participate in GVC networks. In the case of emerging economies, the quality and efficiency of the transportation system is capable to reduce the "remoteness" and bring them closer to country partners by reducing the physical distance and decreasing costs of trade.

With the exception of economic distance, we found some significant interactions for all the other distance dimensions with the national transportation system, particularly for the geographic distance in emerging economies, where the improvement of all the transportation modes – inland, maritime and air – is able to increase GVC-related trade flows. We can assert that the transport sector is an integral part in terms of facilitating GVCs participation as it allows to effectively complete imports and exports of intermediate goods and services that are re-exported in third countries.

The continuing rise of world trade and the desire by many countries to speed up the pace of integration within the global trading system will depend not only on maintaining an open global economic system but improving the quantity and efficiency of the support transport infrastructures.

The improvement of the national transportation system will continue to drive countries around the world to achieve greater participation in the global production network and reap the benefits of the globalising world that offers growing and development opportunities. It is the level of development as well as the within-country transportation system that can be a critical element in terms of allowing countries to participate in GVCs without many constraints and at lower costs.

While improving overall transportation system can be an important step towards shaping long-term facilitation of GVCs participation becomes an important empirical question. This issue is investigated in this work by providing novel evidences with a trade policy research focus that from applied economics perspective are rare.

Our results clearly illustrate that investments in transport infrastructures are required to overcome the obstacle of the national transportation system as a limitation for the country's involvement in GVCs of emerging economies. In particular, the geographic distance was found to be consistently negative, while rising the quality of the national transportation systems (i.e. inland, port, and air transportation) significantly affect

GVCs-related trade flows, for both emerging and developed economies in an import and export perspective respectively. Interestingly, we found the influence of within-country transportation system to reduces the “remoteness” of emerging countries and further increase their GVCs involvement.

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Appendix

Table 7: Econometric results of the effect of the national transportation system in moderating the geographic distance (all, emerging and developed economies).

	All economies		*Emerging economies*		*Developed economies*	
	FVT flows	*DVX flows*	*FVT flows*	*DVX flows*	*FVT flows*	*DVX flows*
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
dGEO	-0.0002 ***	-0.0002 ***	-0.0002 ***	-0.0002 ***	-0.0002 ***	-0.0002 ***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
dWGI	0.1736 ***	0.0921 *	0.2258 ***	0.1826 **	0.2458 ***	0.1024
	(0.05826)	(0.0504)	(0.0743)	(0.0928)	(0.0888)	(0.0689)
dCULT	-0.0680	-0.0617	0.0371	-0.0708	-0.1707 **	-0.1426 **
	(0.0631)	(0.0515)	(0.0893)	(0.0787)	(0.0690)	(0.0593)
dECO	-0.00002 ***	0.0000 ***	0.0000	0.0000	0.0000 ***	0.0000 ***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Border	1.2909 ***	0.9454 ***	1.4133 ***	0.5192 **	1.1874 ***	1.0264 ***
	(0.1453)	(0.1328)	(0.2172)	(0.2445)	(0.1599)	(0.1287)
Pop origin	-0.0021	0.0061 ***	-0.0046 **	0.0056 ***	-0.0063	0.0293 *
	(0.0017)	(0.0016)	(0.0020)	(0.0018)	(0.0185)	(0.0155)
FTA	-1.0993 ***	-0.0388	-0.7825 ***	0.2607	-1.4433 ***	-0.4978 **
	(0.2214)	(0.1897)	(0.2171)	(0.2698)	(0.2711)	(0.2297)
Inland transport	-1.4339	-1.7931	-1.7915	-0.7578	-0.1200	-3.4346 **
	(1.7875)	(1.2983)	(1.9496)	(1.6173)	(2.0216)	(1.4251)
Maritime transport	-0.9209	-1.4587	-1.1916	-0.7796	-0.1231	-2.4943 **
	(1.2881)	(0.8936)	(1.4487)	(1.3512)	(1.4384)	(1.0009)
Air transport	-0.6923	-1.1282	-0.8279	-0.4383	-0.0148	-2.1083 ***
	(0.9178)	(0.7150)	(0.9281)	(0.8467)	(1.0656)	(0.7738)
dGEO x Inland	0.0009 *	0.0005	0.0009 *	0.0008 *	0.0005	0.0002
	(0.0006)	(0.0005)	(0.0005)	(0.0004)	(0.0006)	(0.0006)
dGEO x Maritime	0.0007 *	0.0004	0.0007 *	0.0006	0.0004	0.0001
	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0005)
dGEO x Air	0.0005 *	0.0002	0.0005 *	0.0004	0.0003	0.0001
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Constant	9.4061 ***	7.4969	9.6621 ***	6.3009 ***	10.3191 ***	8.0446 ***
	(0.3963)	(0.4190)	(0.7766)	(0.8406)	(0.9137)	(0.8483)
Obs.	9600	9600	5,040	5,040	4560	4560
Country pair clusters	1600	1600	840	840	760	760
Pseudo R2	0.5176	0.6151	0.5239	0.6499	0.5561	0.6403
Log pseudolikelihood	-9435499	-7501197	-3597924	-3604808	-4854880	-3221278
Wald Chi2	251.85 ***	288.96 ***	156.4 ***	191.11 ***	249.28 ***	341.68 ***

Robust standard error in parenthesis, *** p<0.01, ** p<0.05, * p<0.10. Standard error adjusted for clusters. Statistics robust to heteroskedasticity.