Uluslararası Yönetim Araştırmaları ve Uygulamaları Dergisi
Journal of International Management Research and Applications
Cilt/Volume: 2 | Sayı/Issue: 2 | Aralık/December 2023

INTERNATIONAL TRADE NETWORK AND THE GRAVITY MODEL*

Hasan Karaboğa[1]
Halit Yanıkkaya[2]

Makale İlk Gönderim Tarihi / First Received: *24.11.2023*

Makale Kabul Tarihi /Accepted: *21.12.2023*

Atıf/©: Karaboğa H., & Yanıkkaya H. (2023). International Trade Network and The Gravity Model. *Journal of International Management Research and Applications*, *2*(2), 18-35.

Abstract

In this paper, we analyze the effects of geographical characteristics and trade network positions of the countries on the international trade. For this purpose, we employ a gravity model of international trade and combine gravity, network, and trade datasets for the years between 1995 and 2010. In this study, country-specific properties such as GDP, population, and other geographical variables for the countries are emplyed. Besides, we also divide the data into developed and developing countries to analyze the differences among countries in terms of economic development. Apart from explanatory variables which are country-specific properties, network variables such as degree, strength, closeness, and eigenvector are utilized. Our findings show that the network variables positively and significantly affect bilateral trade. Since these variables are related with the position of the countries in the network, we conclude that countries having central role in international trade network involve in higher trade volumes.

Keywords: International Trade Network, Gravity Model, Geography.

ULUSLARARASI TİCARET AĞI VE ÇEKİM MODELİ

Özet

Bu makalede, ülkelerin coğrafi özelliklerinin ve ticaret ağındaki konumlarının uluslararası ticaretteki etkilerini analiz edilmektedir. Bu amaçla, uluslararası ticarette bir tür çekim modeli kullanılmakta ve 1995 ile 2010 arasındaki yıllar için çekim, ağ ve ticaret veri setlerini birleştirilmektedir. Bu çalışmada, ülkeler için GSYİH, nüfus ve diğer coğrafi değişkenler gibi ülkeye özgü özellikleri kullanılmaktadır. Ayrıca iktisadi gelişmişlik açısından ülkeler arasındaki farklılıkları analiz etmek için verileri gelişmiş ve gelişmekte olan ülkeler olarak da ayrılmaktadır. Ülkeye özgü özellikler olan açıklayıcı değişkenlerin yanı sıra derece, kuvvet, yakınlık ve özvektör gibi ağ değişkenleri de kullanılmaktadır. Bulgularımız ağ değişkenlerinin ikili ticareti olumlu ve anlamlı bir şekilde etkilediğini göstermektedir. Bu değişkenler, ülkelerin ağdaki konumlarıyla ilgili olduğu için, uluslararası ticaret ağında merkezi role sahip olan ülkelerin daha yüksek ticaret hacimlerine sahip olduğu sonucuna varılmaktadır.

Anahtar Kelimeler: Uluslararası Ticaret Ağı, Çekimi Modeli, Coğrafya.

[1]Postdoctoral Researcher, Department of Economics, Koç University, Corresponding author, hasan@karaboga.com, ORCID: 0000-0001-7166-8700
[2]Professor Department of Economics, Gebze Technical University, halityanikkaya@gtu.edu.tr, ORCID: 0000-0003-1542-0174
*This paper is based on Hasan Karaboga's Ph.D. thesis on Economics, in 2022.

1. INTRODUCTION

The geographical characteristics of the countries have been generally neglected in the traditional theories of international trade. In these models, the comparative advantages of countries determine both the level and direction of trade with each other. Instead of the traditional Heckscher-Ohlin model, Krugman's new economic geography model becomes widespread in the literature in the 1990s. To explain the differences in trade caused by geographical distances between countries, the gravity equation in physics was firstly adapted by Tinbergen (1962) to international trade. This model has been widely used in the literature and developed in many perspectives.

The gravity model successfully explains the trade flows; however, the interaction and link formation of the countries are also worth thinking about. This idea brings us to the international trade network literature. According to these network models, which are defined as "International Trade Network" (ITN), "World Trade Network" (WTN) or "World Trade Web" (WTW), countries are treated as nodes and trade between them is shown as links and network indices are calculated. Trade networks are complex systems and explain the interaction of trade partners in terms of their links. The network theory usually deals with the connections which are irrelevant of geography. An increasing number of studies treats international trade as a complex system and employs network techniques to discover the topological properties of the trade network.

In this paper, the gravity model with the network approach of international trade is employed and we try to explore the trade effects of network and geographical characteristics of the countries. For this purpose, gravity, network, and trade datasets from the CEPII are combined and the factors affecting the trade flows in the international trade network are analyzed. Main innovation of this work is bringing these datasets together and analyzing the international trade network and the gravity model both with all countries and considering developed and developing countries separately. We organize this paper as follows. The next section reviews the literature. The third section describes the data, the fourth section explains the methodology, and the fifth section discusses the empirical results. And finally, the sixth section concludes.

2. LITERATURE REVIEW

An increasing number of studies treats international trade as a complex system and employs network techniques to discover the topological properties of the trade network. Hilgerdt (1943) is a seminal effort defining international trade as a network. A later work, Smith and White (1992) analyze the structure of the trade network by using the relational distance algorithm and find that the countries are slowly altering from their positions over time, which are defined as the core, semi-periphery, and periphery.

Garlaschelli and Loffredo (2005) define the world trade web as a directed and evolving network and affirm the phenomenon of relationship between this topology and wealth of the countries. Serrano and Boguna (2003) find that the international trade network shows complex network features, and it addresses topological features of the network. They argue that international trade must be considered as a whole, complex system since the globalization tends to eliminate most of the geographical, economic, and technical limitations.

Another work, Kali and Reyes (2007) suggest a network approach to international economic integration instead of the classical measures based on trade volumes. They find that a country's economic growth and its network position are strongly related. Schweitzer et al. (2009) concern with challenges originated

from the global crisis that affects the whole complex system. They argue that economic policies favoring network structures resistant to economic shocks should be proposed.

Substantial efforts in the ITN literature deals especially with the topological properties of the network. Topology refers to the metrics like degree, strength as we discussed above. They employ various examinations to discuss these networks properties. Fagiolo et al. (2008) examine the topology of trade network by employing a weighted-network analysis. They show that most of the trade links are weak relationships and there is a linear relationship between the intensity of trade connections and clustering.[1] Barigozzi et al. (2010) and Barigozzi et al. (2011) are another strand of the literature related with the topological properties of ITN, which analyzes the commodity-specific trade relations. De Benedictis et al. (2014) is a comprehensive paper analyzing world trade using network techniques. Working with the CEPII BACI dataset for the years between 1995 and 2010, they calculate local and global centrality measures for the countries and describe the binary and weighted topology of the trade network with supporting network representations both in aggregate and sectoral levels.

The gravity model is widely used in the international trade literature as we discussed in the introduction part. Chaney (2008) employs a type of gravity model which deals with intensive and extensive margin of trade with firm heterogeneity in productivity. Chaney (2014) studies the frictions in the international trade since they have importance on affecting the trade between countries. According to this work, the exports of the firms are only directed to the markets that they have a contact. Thus, the dynamic formation of the exporters' network in the is characterized by the theory of the study with trade frictions.

Some works on the ITN literature deal with the shortcomings of the gravity model. They argue that the gravity model cannot estimate the zero trade flows, which results in failure in reproducing links in the trade network. To overcome this drawback, Picciolo et al. (2012) employ exponential random graphs and treat distances as constraints. They conclude that trade network does not strongly depend on the distances between countries. Squartini and Garlaschelli (2014) suggest a probabilistic approach taken from the physics, by adopting quantum-mechanical paradigm. Their results indicate that these methods explain binary topological properties much better than weighted metrics of the international trade network.

Another strand of the ITN literature combines network indices with the gravity model for empirical analysis. De Benedictis and Tajoli (2011) utilize network metrics such as density, closeness, betweenness, and degree centrality as well as various country characteristics such as income, population, and geographical location. They employ these network metrics as dependent variables in a classical gravity equation on the traditional country-specific variables to provide additional explanatory power. Duenas and Fagiolo (2013) also explain the international trade network through the gravity model. According to the authors, the gravity model is insufficient to account for the high-level statistics such as clustering. To explain the topological properties of the network, the gravity model and network-related variables should be combined.

Our contribution in this work to the ITN literature is to employ the gravity model with the network approach of international trade and empirically examine the trade effects of characteristics and network indices of the countries. For this purpose, we combine gravity, network, and trade datasets from the CEPII and analyze the factors affecting flows in the trade network to discover the dynamics of ITN. Main innovation of this work is not only to bring these datasets together but also is to analyze the impact

[1]See Fagiolo et al. (2009) and Fagiolo (2010) for the related work.

of geography and international trade network on trade by considering developed and developing countries separately.

3. DATA

We basically combine three datasets together which are taken from the CEPII for 178 countries. Firstly, trade data is from the BACI dataset based on UN Comtrade[2] dataset. Export volumes come from this dataset. Originally, the BACI dataset is disaggregated at the Harmonized System (HS) 6 level, and we then aggregate export shares as of total export of each country to another. We also make use of the network trade dataset, which includes network indices. These are out-degree, out-strength, out-closeness, and out-eigenvector centrality. Lastly, we include the gravity dataset, which is consisted of the geographical characteristics of countries[3]; which are the weighted distance, GDP per capita, population, area, contiguity, common currency, common language, and GATT/WTO membership. Note that, the CEPII BACI dataset covers the years between 1995 and 2015. However, since the network trade dataset lasts by the year 2010, our combined dataset is limited by the years 1995 and 2010.

Table 1 displays the descriptive statistics. Export and GDP per capita values are in thousand dollars and deflated by 2010 U.S. CPI. In our dataset, export and GDP per capita observations are thus much fewer than the other variables we have since there are some missing values for some of the countries and years. Variables are named as the "origin" for country i, and the "destination" for country j. For these variables, understandably, summary statistics take the same values.

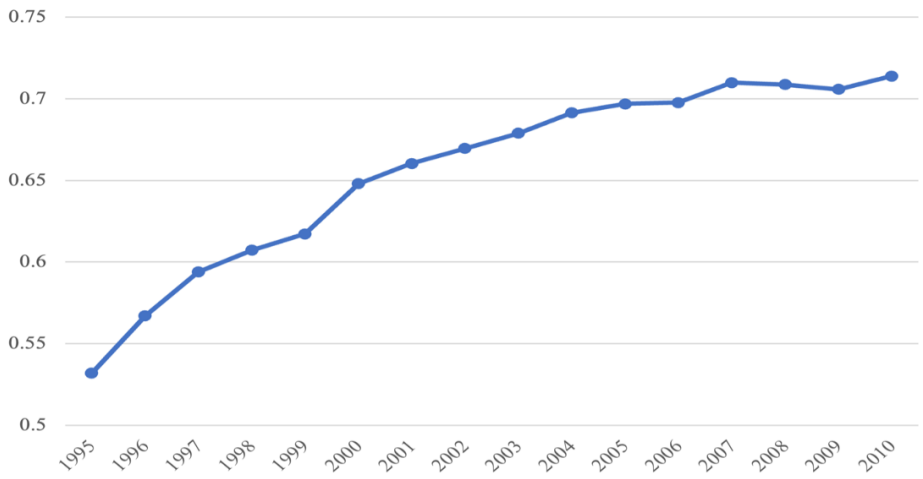
Table 1. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Export	299186	$2.19x10^9$	$5.49x10^{11}$	930.91	$2.96x10^{14}$
Distance (km)	504096	7929.49	4497.06	60.77	19781.39
Origin GDP per capita	434004	38034.39	1201817	207.37	$5.95x10^7$
Destination GDP per capita	434004	38034.39	1201817	207.37	$5.95x10^7$
Origin population (million)	503565	35.29	129.08	0.02	1337.71
Destination population (million)	503565	35.29	129.08	0.02	1337.71
Origin area (km^2)	504096	741708.1	1983853	25	$1.71x10^7$
Destination area (km^2)	504096	741708.1	1983853	25	$1.71x10^7$
Contiguity	504096	0.02	0.13	0	1
Common currency	504096	0.01	0.10	0	1
Common language	504096	0.14	0.35	0	1
GATT/WTO (origin)	504096	0.74	0.44	0	1
GATT/WTO (destination)	504096	0.74	0.44	0	1
Out-degree centrality	504096	0.65	0.25	0.05	1
Out-strength centrality	504096	1829488	2591063	500.55	9996222
Out-closeness centrality	504096	0.77	0.15	0.51	1
Out-eigenvector centrality	504096	0.07	0.02	0.01	0.11

[2]See Gaulier and Zignago (2010).
[3]See Head et al. (2010) and Head and Mayer (2014).

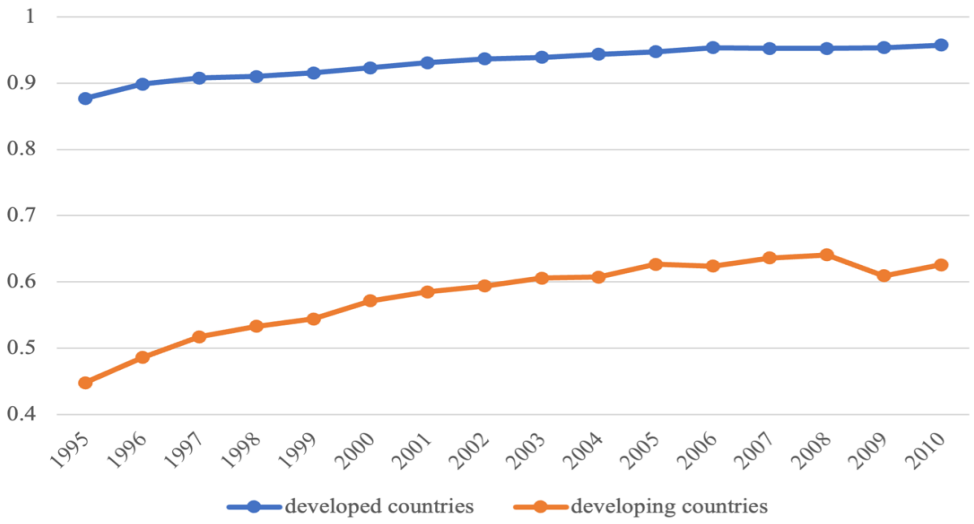
In this section, we represent network related figures and tables below by employing our 178-country dataset described above. Since the aim of our empirical analysis in this paper is to explain the dynamic changes in the international trade from the network perspective, we first calculate the density of the whole trade network, following De Benedictis et al. (2014). The density is defined as the proportion of actual trade links to maximum possible ones. We can observe from Figure 1 that, the density of ITN mostly increases between the years 1995 to 2010, except from the years near 2008 financial crisis.

Figure 1. Network Density of 178 Countries



For the links indicating trade flows out and in, we calculate and demonstrate the change in average values of out-degree and in-degree centralities. Figures 2 and 3 present the difference between out and in trade flows. We also divide data for 35 developed and 143 developing countries[4] to see how different countries behave over time. Note that, degree centralities are calculated for each country, then we take the averages of these values for 178 countries.

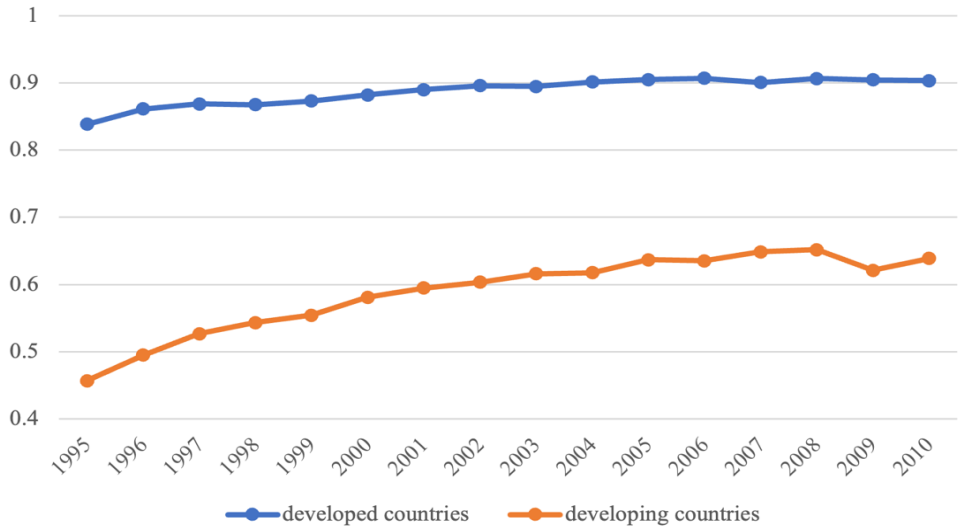
Figure 2. Average Out-Degree Centrality



[4]See Appendix for these countries.

Figure 2 shows the average out-degree centralities of developed and developing countries. For the developed countries, values range between 0.88 and 0.95 for the years between 1995 and 2010. Developing countries' average out-degree centrality starts from 0.45 in 1995 and increases to 0.65 in 2008. After the 2008 global crisis, we observe a decline especially for the developing countries though.

Figure 3. Average In-Degree Centrality



As can be seen from Figure 3, similarly, the average in-degree centralities for the developed countries increases from 0.84 to 0.90. Developing countries' in-degree centralities come up against a decline from 0.65 to 0.62 after the crisis, which has increased steadily from 0.45 since 1990. These two figures indicate that developed countries have substantially higher degree centralities and the position of developed countries in the trade network is less affected from the 2008 crisis than that of developing countries is.

Table 2. Out-Strength Centrality (1995 and 2010)

1995			2010		
Rank	Country	Out-strength	Rank	Country	Out-strength
1	U.S.	3384770	1	China	9996222
2	Germany	2786351	2	Germany	6705292
3	Japan	2579884	3	U.S.	6610431
4	France	1539471	4	Japan	4415181
5	UK	1284979	5	France	2880275
6	Italy	1255030	6	South Korea	2679725
7	China	1151677	7	Italy	2424068
8	Canada	1063366	8	Netherlands	2356322
9	Netherlands	957603	9	UK	2187866
10	Belgium	857750	10	Canada	2142547
…			…		
169	Seychelles	402.882	169	Saint Vincent	786.511
170	Armenia	354.513	170	Maldives	759.471

171	Samoa	324.756	171	Central African R.	686.148
172	Bosnia and Her.	312.950	172	Guinea-Bissau	524.097
173	Antigua and Bar.	265.744	173	Saint Lucia	480.173
174	Rwanda	251.977	174	Samoa	467.743
175	Bhutan	240.245	175	Saint Kitts.	394.072
176	Saint Kitts	234.620	176	Gambia	371.713
177	Marshall Isl.	156.370	177	Dominica	323.509
178	Vanuatu	151.737	178	Micronesia	307.672

In Table 2, we list 10 countries with highest and 10 with lowest out-strength centrality for the years 1995 and 2010, which are the first and the last years of our dataset. The strength centrality is simply trade weighted version of degree centrality. Thus, we can claim that countries with high trade volumes and trade links have also high out-strength centralities. For example, we can easily see the surge of China to the first rank in 2010 due to its recent spectacular performance in the world trade.

Table 3. Out-Closeness Centrality (1995 and 2010)

1995			2010		
Rank	Country	Out-closeness	Rank	Country	Out-closeness
1	Belgium	1	1	China	1
2	Denmark	1	2	Germany	1
3	Germany	1	3	U.S.	1
4	Italy	1	4	France	1
5	Netherlands	1	5	Italy	1
6	Sweden	1	6	Netherlands	1
7	UK	1	7	UK	1
8	China	0.994	8	Spain	1
9	Japan	0.989	9	India	1
10	U.S.	0.989	10	Malaysia	1
…			…		
169	Bhutan	0.550	169	Equatorial G.	0.586
170	Guinea-Bissau	0.550	170	Saint Lucia	0.584
171	Saint Kitts	0.550	171	Saint Kitts	0.582
172	Solomon Isl.	0.546	172	Marshall Isl.	0.577
173	Equatorial G.	0.543	173	Samoa	0.571
174	Iraq	0.538	174	Vanuatu	0.567
175	Samoa	0.536	175	Bhutan	0.567
176	Vanuatu	0.532	176	Solomon Isl.	0.560
177	Marshall Isl.	0.521	177	Guinea-Bissau	0.557
178	Micronesia	0.513	178	Micronesia	0.545

Closeness and eigenvector centralities in principle measure different values. The former can be defined as easiness of a node when reaching to other nodes, whereas the latter quantifies the importance of linked neighbors of the node. In Table 3 and Table 4, we demonstrate the top and bottom 10 countries with

out-closeness and out-eigenvector centralities in 1995 and 2010. We rank the countries with their out-strength centrality if their closeness or eigenvector centralities are equal. We observe that although the ranking is somewhat different, both two list consist of very similar countries. The reason for this is probably a country which easily reach to another country, having high closeness centrality, has also important neighbors, having high eigenvector centrality.

Table 4. Out-Eigenvector Centrality (1995 and 2010)

1995			2010		
Rank	Country	Out-eigenvector	Rank	Country	Out-eigenvector
1	Germany	0.112	1	China	0.096
2	UK	0.112	2	Germany	0.096
3	Italy	0.112	3	U.S.	0.096
4	Netherlands	0.112	4	France	0.096
5	Belgium	0.112	5	Italy	0.096
6	Sweden	0.112	6	Netherlands	0.096
7	Denmark	0.112	7	UK	0.096
8	China	0.112	8	Spain	0.096
9	Switzerland	0.111	9	India	0.096
10	Japan	0.111	10	Malaysia	0.096
…			…		
169	Solomon Isl.	0.029	169	Equatorial G.	0.034
170	Bhutan	0.028	170	Saint Lucia	0.033
171	Aruba	0.025	171	Saint Kitts	0.033
172	Saint Kitts	0.024	172	Marshall Isl.	0.032
173	Equatorial G.	0.024	173	Samoa	0.029
174	Samoa	0.023	174	Bhutan	0.028
175	Iraq	0.022	175	Vanuatu	0.028
176	Vanuatu	0.020	176	Solomon Isl.	0.026
177	Marshall Isl.	0.014	177	Guinea-Bissau	0.024
178	Micronesia	0.009	178	Micronesia	0.020

4. METHODOLOGY

To discover the impacts of the geography and ITN on trade, we first combine both network indices and country-specific characteristics with the gravity model, based on the earlier studies such as De Benedictis and Tajoli (2011). The gravity model provides us to find the geographical effects on bilateral trade of the countries, which is frequently used in the trade literature. In our model, we incorporate the network indices to determine how the network positions of the countries affect the bilateral trade. Network indices used in this analysis are degree, strength, closeness, and eigenvector centrality. We also put country characteristics such as GDP, population, and geographical properties in the following gravity equation.

$$\ln T_{i,j} = \beta_0 + \beta_1 lnX_{i,j} + \beta_2 lnC_i + \beta_3 lnC_j + \beta_4 D_{i,j} + ln\beta_5 N_{i,j} + \in_{i,j} \quad (1)$$

In this model, T denotes trade flow from country i to country j. The distance between the countries is shown as X in the model. C_i and C_j are country-specific properties such as GDP per capita, population, and area. Dummy variables are also added to the model, which are contiguity, common currency, common language, and GATT/WTO membership, denoted by $D_{i,j}$. Finally, $N_{i,j}$ denotes network indices, and we only use "out" values of these indices since we assume trade flows as exports from country i to country j.

We note that our model has shortcoming in explaining bilateral trade with network variables, which is the endogeneity bias. Our dependent variable is exports, and we employ network centralities as independent variables. However, there is a possible reverse causality issue between these variables since the trade volume might have impact on the network position of the country. We leave this issue for the future research.

5. EMPIRICAL RESULTS

Firstly, we perform the OLS regressions with four centrality measures for all countries. We then estimate our model for four different country groupings. We begin with our regression results concerning the geographical and network effects on exports with our dataset for all countries, which are displayed in Table 5. We perform the regressions for out-degree, out-strength, out-closeness, and out-eigenvector centralities individually and report the results in four columns in the table respectively. All centralities have positive effect on exports, and the coefficient of out-closeness centrality is the greatest one. It is interesting that the coefficient of out-strength centrality is lower than out-degree centrality. That is, if we weigh trade links by trade volumes for strength centrality instead of calculating degree centrality using the number of trade links, the effect of network on trade would be lower. We also find that out-eigenvector centrality has positive impact on exports.

As expectedly, the distance between the countries negatively affects the trade volume. GDP and population of both the origin and the destination countries have positive and significant coefficients. The areas of the countries have negative effects on the bilateral trade. Almost all dummies apart from a GATT membership of the origin country have significantly positive coefficients.

Table 5. ITN and Exports (All Countries)

ln (export)	(1)	(2)	(3)	(4)
ln (weighted distance)	-1.146***	-1.170***	-1.150***	-1.145***
	(0.006)	(0.006)	(0.006)	(0.006)
ln (origin GDP per capita)	0.976***	1.139***	0.845***	0.990***
	(0.004)	(0.003)	(0.004)	(0.004)
ln (destination GDP per capita)	0.916***	0.895***	0.925***	0.911***
	(0.003)	(0.003)	(0.003)	(0.003)
ln (origin population)	0.987***	1.171***	0.873***	1.003***
	(0.004)	(0.004)	(0.005)	(0.004)
ln (destination population)	1.021***	1.002***	1.027***	1.020***
	(0.004)	(0.004)	(0.004)	(0.004)
ln (origin area)	-0.067***	-0.094***	-0.052***	-0.071***
	(0.003)	(0.003)	(0.003)	(0.003)
ln (destination area)	-0.139***	-0.136***	-0.139***	-0.140***
	(0.003)	(0.003)	(0.003)	(0.003)

Contiguity	1.233***	1.175***	1.243***	1.225***
	(0.028)	(0.029)	(0.028)	(0.028)
Common currency	0.848***	0.726***	0.787***	0.874***
	(0.035)	(0.035)	(0.034)	(0.035)
Common language	1.057***	0.982***	1.080***	1.054***
	(0.012)	(0.012)	(0.012)	(0.012)
GATT/WTO (origin)	0.083***	0.329***	-0.030**	0.135***
	(0.012)	(0.012)	(0.012)	(0.012)
GATT/WTO (destination)	0.283***	0.278***	0.288***	0.300***
	(0.012)	(0.012)	(0.012)	(0.012)
ln (out-degree centrality)	1.387***			
	(0.019)			
ln (out-strength centrality)		0.034***		
		(0.002)		
ln (out-closeness centrality)			4.488***	
			(0.043)	
ln (out-eigenvector centrality)				1.589***
				(0.023)
Constant	6.745***	4.553***	8.458***	10.22***
	(0.078)	(0.078)	(0.081)	(0.107)
Observations	265,154	265,154	265,154	265,154
R-squared	0.667	0.661	0.674	0.666
F-Test	40905.22	39718.12	42086.55	40745.60
RMSE	2.1196	2.1196	2.1404	2.0994

Notes: Standard errors in parentheses. ***, **, and * denote 1, 5, and 10 percentages of significance.

For the second step, we estimate our model for the two groups of countries, developed and developing, with each four centrality measures. We report the regressions for out-degree, out-strength, out-closeness, and out-eigenvector centralities in the Appendix. The first column of each table (1-1) shows the trade flows between developed countries, and the second column (0-0) displays trade flows between developing countries. The third column (1-0) is the regression results for the export flows from developed countries to developing countries, and the fourth column (0-1) is vice versa.

Like the full sample regressions, we obtain very similar results for these four sub-groups for the distance, GDP per capita, and the population. However, the areas of the origin and the destination country now raise bilateral trade volumes when the flow is between developed countries, otherwise it has negative trade effect as we report regressions for all countries. Almost all dummy variables have positive and significant effects on trade. When the trade flows from developing country to developed country, both country's GATT memberships negatively affect the trade. If the trade flows from developed to developing country, the origin country's GATT membership has negative effect whereas the destination has positive effect on bilateral trade.

All centralities positively affect the export volumes except out-strength centrality when the flow is between developing to developed country. In this case, out-strength centrality of developing country has statistically significant and negative effect on export of developing country to developed country. Like

in all country regressions, the coefficient of out-strength centrality is smaller than other centralities for all versions of trade flows between developed and developing countries.

6. CONCLUSION

In this paper, we begin with defining the basic concepts of network theory, and then we combine gravity, network, and trade datasets from the CEPII, to analyze the effects of country-specific properties and network indices on the international trade. We also separate our data into developed and developing countries to observe the differences between the groups of countries. By using the gravity model with the network indices, we first analyze the factors affecting export volumes for all countries, and then for the flows between developed and developing countries.

When we look at the trade flows for all countries, we find that centrality measures, which are out-degree, out-strength, out-closeness, and out-eigenvector centrality, significantly raise countries' bilateral trade. These measures are related to the position of the countries in the network. Thus, countries with high centralities are more likely to have higher trade volumes than the others have. We re-run the regressions for the four sub-group of countries and evaluate the differences when the flow is from a developed or a developing country. Our results show that apart from developed countries, developing countries with high centrality measures tend to have higher trade volumes.

REFERENCES

Barigozzi, M., Fagiolo, G., & Garlaschelli, D. (2010). Multinetwork of international trade: A commodity-specific analysis. *Physical Review E, 81*(4), 046104.

Barigozzi, M., Fagiolo, G., & Mangioni, G. (2011). Identifying the community structure of the international-trade multi-network. *Physica A: Statistical Mechanics and Its Applications, 390*(11), 2051–2066.

Chaney, T. (2008). Distorted Gravity: The Intensive and Extensive Margins of International Trade. *American Economic Review, 98*(4), 1707–1721.

Chaney, T. (2014). The network structure of international trade. *American Economic Review, 104*(11), 3600-3634.

De Benedictis, L., Nenci, S., Santoni, G., Tajoli, L., & Vicarelli, C. (2014). Network analysis of world trade using the BACI-CEPII dataset. *Global Economy Journal*, *14*(03n04), 287-343.

De Benedictis, L., & Tajoli, L. (2011). The world trade network. *The World Economy*, *34*(8), 1417-1454.

Dueñas, M., & Fagiolo, G. (2013). Modeling the International-Trade Network: A gravity approach. *Journal of Economic Interaction and Coordination, 8*, 155-178.

Fagiolo, G. (2010). The international-trade network: Gravity equations and topological properties. *Journal of Economic Interaction and Coordination, 5*, 1-25.

Fagiolo, G., Reyes, J., & Schiavo, S. (2008). On the topological properties of the world trade web: A weighted network analysis. *Physica A: Statistical Mechanics and Its Applications, 387*(15), 3868-3873.

Fagiolo, G., Reyes, J., & Schiavo, S. (2009). World-trade web: Topological properties, dynamics, and evolution. *Physical Review E, 79*(3), 036115.

Garlaschelli, D., & Loffredo, M. I. (2005). Structure and evolution of the world trade network. *Physica A: Statistical Mechanics and Its Applications, 355*(1), 138-144.

Gaulier, G., & Zignago, S. (2010). BACI: International Trade Database at the Product-Level (the 1994-2007 Version).

Head, K., & Mayer, T. (2014). Gravity Equations: Workhorse,Toolkit, and Cookbook. *In Handbook of International Economics* 4, 131–195. Elsevier.

Head, K., Mayer, T., & Ries, J. (2010). The erosion of colonial trade linkages after independence. *Journal of International Economics, 81*(1), 1–14.

Hilgerdt, F. (1943). The case for multilateral trade. *The American Economic Review*, *33*(1), 393-407.

Kali, R., & Reyes, J. (2007). The architecture of globalization: A network approach to international economic integration. *Journal of International Business Studies, 38*, 595-620.

Picciolo, F., Squartini, T., Ruzzenenti, F., Basosi, R., & Garlaschelli, D. (2012). The role of distances in the World Trade Web. In *2012 Eighth International Conference on Signal Image Technology and Internet Based Systems* (784-792). IEEE.

Schweitzer, F., Fagiolo, G., Sornette, D., Vega-Redondo, F., Vespignani, A., & White, D. R. (2009). Economic networks: The new challenges. *Science*, *325*(5939), 422-425.

Serrano, M. Á., & Boguñá, M. (2003). Topology of the world trade web. *Physical Review E*, *68*(1), 015101.

Smith, D. A., & White, D. R. (1992). Structure and dynamics of the global economy: Network analysis of international trade 1965-1980. *Social Forces*, *70*(4), 857–893.

Squartini, T., & Garlaschelli, D. (2014). Jan Tinbergen's Legacy for Economic Networks: From the Gravity Model to Quantum Statistics. *In Econophysics of Agent-Based models* (161–186). Springer International Publishing.

Tinbergen, J. (1962). *Shaping the World Economy; Suggestions for an International Economic Policy*. New York: The Twentieth Century Fund.

APPENDIX

Table A1. Developed Countries

Developed Countries		
Australia	Germany	Norway
Austria	Greece	Poland
Belgium	Hungary	Portugal
Bulgaria	Iceland	Romania
Canada	Ireland	Slovakia
Croatia	Italy	Slovenia
Cyprus	Japan	Spain
Czech Republic	Latvia	Sweden
Denmark	Lithuania	Switzerland
Estonia	Malta	United Kingdom
Finland	Netherlands	United States
France	New Zealand	

Table A2. Developing Countries

Developing Countries	
Afghanistan	Dem. Peop. Rep. of Korea
Albania	Dem. Rep. of the Congo
Algeria	Dominica
Angola	Dominican Rep.
Antigua & Barbuda	Ecuador
Argentina	Egypt
Armenia	El Salvador
Aruba	Equatorial Guinea
Azerbaijan	Ethiopia
Bahrain	Fiji
Bangladesh	FMR Sudan
Barbados	FS Micronesia
Belarus	Gabon
Belize	Gambia
Benin	Georgia
Bermuda	Ghana
Bhutan	Guatemala
Bolivia	Guinea
Bosnia Herzegovina	Guinea-Bissau
Br. Virgin Isds	Guyana
Brazil	Haiti
Brunei Darussalam	Honduras
Burkina Faso	Hong Kong
Burundi	India
Cambodia	Indonesia
Cameroon	Iran
Cayman Isds	Iraq
Central African Rep.	Israel
Chad	Jamaica
Chile	Jordan
China	Kazakhstan
Colombia	Kenya
Congo	Kuwait
Costa Rica	Kyrgyzstan
Côte dIvoire	Lao Peop. Dem. Rep.
Cuba	Lebanon

Table A2. Developing Countries (continued)

Developing Countries	
Liberia	Saint Vincent & Grenadines
Libya	Samoa
Macao	Saudi Arabia
Madagascar	Senegal
Malawi	Serbia and Montenegro
Malaysia	Seychelles
Maldives	Sierra Leone
Mali	Singapore
Marshall Isds	So. African Customs Union
Mauritania	Solomon Isds
Mauritius	Somalia
Mexico	Sri Lanka
Mongolia	Suriname
Morocco	Syria
Mozambique	Taiwan
Myanmar	Tajikistan
Nepal	TFYR of Macedonia
Neth. Antilles	Thailand
New Caledonia	Togo
Nicaragua	Trinidad and Tobago
Niger	Tunisia
Nigeria	Turkey
Oman	Turkmenistan
Pakistan	Uganda
Panama	Ukraine
Papua New Guinea	United Arab Emirates
Paraguay	United Rep. of Tanzania
Peru	Uruguay
Philippines	Uzbekistan
Qatar	Vanuatu
Republic of Korea	Venezuela
Republic of Moldova	Viet Nam
Russian Federation	Yemen
Rwanda	Zambia
Saint Kitts and Nevis	Zimbabwe
Saint Lucia	

Table A3. Out-Degree Centrality and Exports

ln (export)	1-1	0-0	1-0	0-1
ln (weighted distance)	-1.006***	-1.232***	-1.203***	-0.685***
	(0.008)	(0.009)	(0.012)	(0.015)
ln (origin GDP per capita)	0.893***	0.965***	1.180***	0.974***
	(0.011)	(0.006)	(0.011)	(0.008)
ln (destination GDP per capita)	0.827***	0.711***	0.879***	1.033***
	(0.010)	(0.005)	(0.005)	(0.014)
ln (origin population)	0.822***	0.926***	1.045***	0.982***
	(0.008)	(0.007)	(0.008)	(0.010)
ln (destination population)	0.780***	0.980***	1.015***	1.342***
	(0.006)	(0.006)	(0.006)	(0.008)
ln (origin area)	0.019***	-0.068***	-0.095***	-0.048***
	(0.006)	(0.005)	(0.005)	(0.006)
ln (destination area)	0.031***	-0.184***	-0.151***	-0.262***
	(0.006)	(0.005)	(0.004)	(0.007)
Contiguity	0.539***	1.430***	1.339***	2.389***
	(0.032)	(0.038)	(0.094)	(0.121)
Common currency	0.0912***	1.206***	0.872***	0.722*
	(0.026)	(0.052)	(0.322)	(0.413)
Common language	0.690***	0.864***	1.007***	1.246***
	(0.030)	(0.018)	(0.023)	(0.031)
GATT/WTO (origin)	0.089*	0.173***	-0.385***	-0.271***
	(0.048)	(0.018)	(0.056)	(0.023)
GATT/WTO (destination)	0.292***	0.245***	0.088***	-0.355***
	(0.039)	(0.017)	(0.016)	(0.062)
ln (out-degree centrality)	1.189***	1.590***	2.664***	1.757***
	(0.104)	(0.030)	(0.115)	(0.035)
Constant	5.527***	10.02***	6.378***	3.358***
	(0.159)	(0.134)	(0.169)	(0.201)
Observations	19,036	126,861	61,250	58,007
R-squared	0.858	0.549	0.727	0.672
F-Test	8803.46	11853.81	12526.17	9128.02
RMSE	0.94	2.37	1.64	2.10

Notes: Standard errors in parentheses. ***, **, and * denote 1, 5, and 10 percentages of significance levels, respectively.

Table A4. Out-Strength Centrality and Exports

ln (export)	1-1	0-0	1-0	0-1
ln (weighted distance)	-1.011***	-1.212***	-1.205***	-0.724***
	(0.008)	(0.009)	(0.012)	(0.015)
ln (origin GDP per capita)	0.843***	1.135***	1.090***	1.152***
	(0.013)	(0.006)	(0.013)	(0.007)
ln (destination GDP per capita)	0.827***	0.691***	0.875***	1.018***
	(0.010)	(0.005)	(0.005)	(0.014)
ln (origin population)	0.795***	1.188***	0.989***	1.294***
	(0.009)	(0.006)	(0.009)	(0.008)
ln (destination population)	0.779***	0.955***	1.011***	1.312***
	(0.006)	(0.006)	(0.006)	(0.008)
ln (origin area)	0.0276***	-0.116***	-0.0787***	-0.110***
	(0.006)	(0.004)	(0.005)	(0.006)
ln (destination area)	0.0331***	-0.180***	-0.150***	-0.254***
	(0.006)	(0.004)	(0.004)	(0.007)
Contiguity	0.530***	1.370***	1.372***	2.468***
	(0.032)	(0.039)	(0.094)	(0.123)
Common currency	0.0992***	1.015***	0.709**	1.117***
	(0.026)	(0.052)	(0.322)	(0.422)
Common language	0.679***	0.867***	0.971***	1.227***
	(0.030)	(0.018)	(0.023)	(0.031)
GATT/WTO (origin)	0.342***	0.393***	0.149***	0.0112
	(0.040)	(0.017)	(0.048)	(0.022)
GATT/WTO (destination)	0.295***	0.232***	0.0909***	-0.183***
	(0.039)	(0.017)	(0.016)	(0.064)
ln (out-strength centrality)	0.0934***	0.0654***	0.188***	-0.00731*
	(0.008)	(0.003)	(0.008)	(0.004)
Constant	4.505***	6.928***	4.184***	1.249***
	(0.143)	(0.134)	(0.150)	(0.209)
Observations	19,036	126,861	61,250	58,007
R-squared	0.858	0.540	0.727	0.657
F-Test	8805.59	11475.25	12520.84	8557.71
RMSE	0.94	2.39	1.64	2.15

Notes: Standard errors in parentheses. ***, **, and * denote 1, 5, and 10 percentages of significance levels, respectively.

Table A5. Out-Closeness Centrality and Exports

ln (export)	1-1	0-0	1-0	0-1
ln (weighted distance)	-1.003***	-1.275***	-1.203***	-0.737***
	(0.008)	(0.009)	(0.012)	(0.015)
ln (origin GDP per capita)	0.860***	0.818***	1.128***	0.890***
	(0.011)	(0.007)	(0.012)	(0.008)
ln (destination GDP per capita)	0.829***	0.726***	0.880***	1.035***
	(0.010)	(0.005)	(0.005)	(0.013)
ln (origin population)	0.797***	0.705***	1.015***	0.863***
	(0.008)	(0.008)	(0.008)	(0.010)
ln (destination population)	0.781***	0.996***	1.016***	1.334***
	(0.006)	(0.006)	(0.006)	(0.008)
ln (origin area)	0.021***	-0.020***	-0.092***	-0.020***
	(0.006)	(0.005)	(0.005)	(0.006)
ln (destination area)	0.030***	-0.185***	-0.151***	-0.255***
	(0.006)	(0.004)	(0.004)	(0.007)
Contiguity	0.544***	1.418***	1.341***	2.228***
	(0.032)	(0.038)	(0.094)	(0.120)
Common currency	0.083***	1.156***	0.934***	0.744*
	(0.026)	(0.051)	(0.322)	(0.409)
Common language	0.687***	0.864***	1.008***	1.198***
	(0.030)	(0.018)	(0.023)	(0.030)
GATT/WTO (origin)	0.048	0.059***	-0.381***	-0.298***
	(0.046)	(0.017)	(0.054)	(0.022)
GATT/WTO (destination)	0.285***	0.259***	0.088***	-0.399***
	(0.039)	(0.017)	(0.016)	(0.062)
ln (out-closeness centrality)	2.287***	5.995***	4.414***	5.416***
	(0.153)	(0.072)	(0.163)	(0.089)
Constant	5.966***	12.31***	6.992***	5.090***
	(0.165)	(0.136)	(0.174)	(0.205)
Observations	19,036	126,861	61,250	58,007
R-squared	0.858	0.563	0.728	0.678
F-Test	8853.51	12565.10	12581.68	9396.21
RMSE	0.94	2.33	1.64	2.08

Notes: Standard errors in parentheses. ***, **, and * denote 1, 5, and 10 percentages of significance levels, respectively.

Table A6. Out-Eigenvector Centrality and Exports

ln (export)	1-1	0-0	1-0	0-1
ln (weighted distance)	-1.010***	-1.227***	-1.207***	-0.676***
	(0.008)	(0.009)	(0.012)	(0.015)
ln (origin GDP per capita)	0.919***	0.981***	1.266***	0.936***
	(0.011)	(0.006)	(0.010)	(0.008)
ln (destination GDP per capita)	0.829***	0.703***	0.873***	1.055***
	(0.010)	(0.005)	(0.005)	(0.013)
ln (origin population)	0.849***	0.959***	1.128***	0.932***
	(0.007)	(0.008)	(0.007)	(0.010)
ln (destination population)	0.778***	0.976***	1.013***	1.348***
	(0.006)	(0.006)	(0.006)	(0.008)
ln (origin area)	0.017***	-0.078***	-0.104***	-0.046***
	(0.006)	(0.005)	(0.005)	(0.006)
ln (destination area)	0.033***	-0.186***	-0.152***	-0.267***
	(0.006)	(0.005)	(0.004)	(0.007)
Contiguity	0.532***	1.420***	1.325***	2.438***
	(0.032)	(0.039)	(0.095)	(0.120)
Common currency	0.122***	1.199***	0.706**	0.647
	(0.026)	(0.052)	(0.323)	(0.411)
Common language	0.690***	0.858***	0.997***	1.255***
	(0.030)	(0.018)	(0.023)	(0.030)
GATT/WTO (origin)	0.289***	0.224***	0.168***	-0.270***
	(0.043)	(0.018)	(0.050)	(0.022)
GATT/WTO (destination)	0.355***	0.255***	0.099***	-0.199***
	(0.040)	(0.017)	(0.017)	(0.062)
ln (out-eigenvector centrality)	0.864***	1.705***	0.811***	2.495***
	(0.123)	(0.038)	(0.123)	(0.044)
Constant	6.922***	13.72***	6.703***	9.137***
	(0.348)	(0.183)	(0.360)	(0.241)
Observations	19,036	126,861	61,250	58,007
R-squared	0.857	0.546	0.725	0.676
F-Test	8759.47	11736.91	12387.99	9287.44
RMSE	0.94	2.37	1.65	2.09

Notes: Standard errors in parentheses. ***, **, and * denote 1, 5, and 10 percentages of significance levels, respectively.