DYNAMICS OF WORLD TRADE NETWORK

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Abstract

This study aims to explain the dynamic changes in the world trade from the network perspective. For this purpose, we use a gravity model of international trade and try to explore the trade effects of country-specific properties and the network indices for these countries. We combine gravity, network, and trade datasets from CEPII for the years between 1995 and 2010. Country-specific properties used in this study are GDP, population, and other geographical properties of the countries. Moreover, to analyze the differences among countries in terms of development, we also divide data into developed and developing countries. Network indices employed apart from the country-specific properties as explanatory variables in this paper are local centrality measures such as degree and strength, and global centrality measures which are closeness and eigenvector. We find that centrality measures positively and significantly affect countries' bilateral trade. Since these measures are actually related to the position of the countries in the network, we conclude that countries with high centralities tend to have higher trade volumes.

Key words: gravity model, network analysis, trade network

JEL Code: F14, C55

Introduction

Countries and regions differ from each other in many aspects. The differences among countries and within the countries have frequently been discussed in the economic growth literature. In the traditional theories of international trade, it has been argued that the absolute and comparative advantages of countries determine trade with each other. In these theories, the geographical features of the countries have generally been neglected though.

To explain the effects of geographical distances, the gravity model in physics was firstly adapted by Tinbergen (1962) to the international trade flows. This model has been widely used in the literature, and developed in many perspectives. By exploiting the gravity model in international trade, we can successfully analyze bilateral trade flows. It is extremely beneficial in explaining bilateral trade flows, whereas there are some difficulties in describing the trade flows as a whole system in gravity models. Recently, network approaches have begun to be developed to eliminate these shortcomings of the gravity model of international trade. The network models of trade try to explain international trade as a complex system and then they can estimate the network's weighted structural properties as well as the binary topology of the network.

In this paper, we use the gravity model with the network approach of international trade and try to explore the trade effects of characteristic properties and network indices. For this purpose, we combine gravity, network, and trade datasets from CEPII and analyze the factors affecting the flows in the international trade network. Main innovation of this work is bringing these datasets together, and analyzing the trade effects of network indices by considering developed and developing countries separately. Our following plan is to analyze the determinants of network centralities of the countries by regarding the network indices as dependent variables.

This paper is organized as follows: In Section 2, we review the literature on the gravity model and network approaches of international trade. Section 3 explains our data and methodology. Lastly, in Section 4, we discuss empirical results of our analysis, and in Section 5, we conclude our discussions.

1 Literature Review

Gravity model in physics had adapted to economics by Tinbergen (1962) and is widely exploited in the international trade literature. According to the model, gravity is calculated proportional to the weights of two locations and inversely proportional to the distance between them. Using this model, usually GDPs and populations of the two countries are taken as weights, and the distance between them are used to find bilateral trade between the countries.

Gravity model in international trade has improved since Tinbergen, and it is used for defining different aspects of trade. For example, Frankel and Romer (1999) suggest geographical variables as alternative instruments of bilateral trade. Basically, they use the gravity model of trade, and argue that bilateral trade between two countries is related to the distance between them. They employ data on distances, populations, area, dummies for landlocked countries and common border countries to estimate bilateral trade over GDP of the countries. They find that the geographical characteristics of countries affect their trade, and trade has the important positive effect on their income.

Although the gravity model is considerably successful in examining international trade flows concerning geographical distances, there are also some shortcomings. For instance, the gravity model cannot predict zero trade flows, and it fails in reproducing the missing links of the world trade network (Squartini and Garlaschelli, 2014). Recently, the models based on the graph theory have also been used in the international trade literature. They are named as “International Trade Network”, “World Trade Network” or “World Trade Web”, and has come in sight from the similar argument. According to these network models, countries are defined as nodes, and trade between them is defined as links and network indices are calculated, and they try to explain international trade flows.

Smith and White (1992) analyze the structure of trade network by using the relational distance algorithm, and find that countries are slowly changing over time from their positions, which are defined as the core, semi-periphery and periphery. Serrano and Boguna (2003) conclude that the international trade network shows complex network features, and it addresses topological features of the network. Fagiolo (2010) also describes the topological features of the international trade network by using an equation modeling.

Duenas and Fagiolo (2013) is another work explaining the international trade network through the gravity model. According to the authors, the gravity model is insufficient to account for high-level statistics such as clustering. They argue that the gravity model and network-related variables might be combined to explain the topological properties of the network. De Benedictis and Tajoli (2011) employ network indices such as density, closeness, betweenness, and degree centrality as well as country characteristics such as income, population, and geographical location. These indices are regressed in the gravity equation, to provide additional explanatory power to the traditional country-specific variables.

2 Data and Methodology

Based on the earlier studies such as De Benedictis and Tajoli (2011), we combine network indices and country-specific characteristics with the gravity model. Network indices used in this work are closeness, betweenness, degree, and eigenvector centrality.[1] Country characteristics such as GDP, population, and geographical properties are also put in the gravity equation.

$$\log T_{i,j} = \beta_0 + log\beta_1 X_{i,j} + log\beta_2 C_i + log\beta_3 C_j + \beta_4 D_{i,j} + log\beta_5 N_{i,j} + \epsilon_{i,j} \quad (1)$$

[1] See, De Benedictis et al. (2013) for the definitions of these measures.

In our 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 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 j.

We basically combine three datasets together in the analysis and all three datasets are taken from CEPII. Firstly, trade data used in this work are from BACI dataset based on COMTRADE[2] dataset. We then also use the network trade dataset, which includes network indices[3] and lastly a gravity dataset, which includes the geographical characteristics of countries[4]. Therefore, this paper employs trade network indices in the gravity equation. Note that all countries take place in the network of trade flows according to their geographical and other characteristics. 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.

Tab. 1 shows the descriptive statistics. Since we have many zero trade flows between some countries or missing values, trade volume observations are much fewer than the other variables have. Trade volume and GDP per capita values are in thousand dollars, and deflated by 2010 US CPI. Variables are named as "the origin" for country i, and "the destination" for country j. For these variables, logically, summary statistics take the same values.

Tab. 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
log trade volume	299186	15.3925	3.65171	6.83616	33.3199
log weighted distance	504096	8.75276	0.76986	4.10711	9.8925
log GDP per capita (the origin)	434004	8.4224	1.54396	5.33452	17.9012
log GDP per capita (the destination)	434004	8.4224	1.54396	5.33452	17.9012
log population (the origin)	503565	1.83821	2.03604	-4.0101	7.19871
log population (the destination)	503565	1.83821	2.03604	-4.0101	7.19871
log area (the origin)	504096	11.4888	2.615	3.21888	16.6532
log area (the destination)	504096	11.4888	2.615	3.21888	16.6532
contiguity dummy	504096	0.01765	0.13167	0	1
common currency dummy	504096	0.01007	0.09982	0	1
common language dummy	504096	0.1434	0.35048	0	1

[2] See Gaulier and Zignago (2010)
[3] See De Benedictis et al. (2013)
[4] See Head et al. (2010) and Head and Mayer (2014)

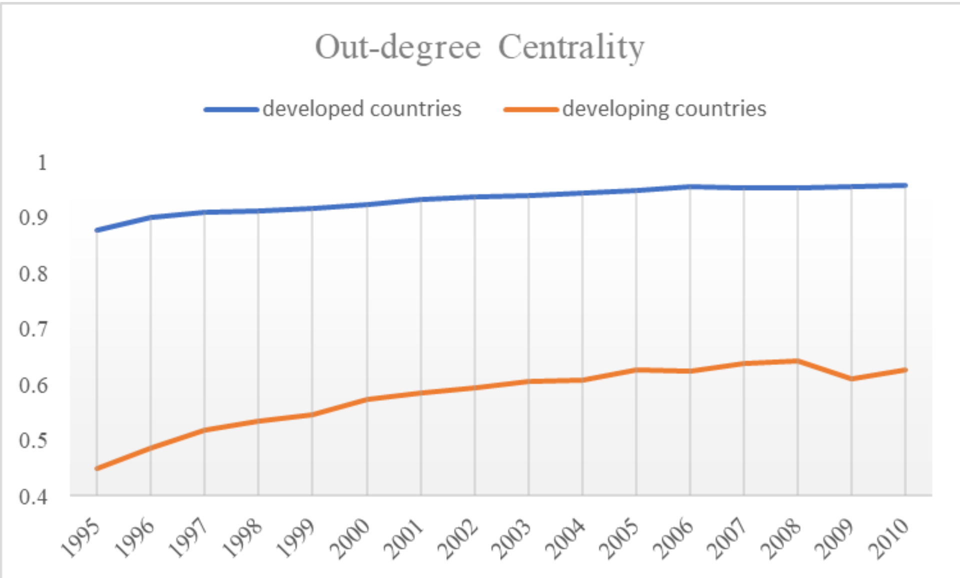
GATT dummy (the origin)	504096	0.73947	0.43893	0	1
GATT dummy (the destination)	504096	0.73947	0.43893	0	1
log out-degree	504096	-0.5297	0.46913	-2.9789	0
log out-strength	504096	12.7061	2.30036	6.21571	16.1177
log out-closeness	504096	-0.2841	0.18936	-0.6674	0
log out-eigenvector	504096	-2.7047	0.38636	-4.7147	-2.1908

Source: BACII, network trade, and gravity datasets from CEPII, discussed above in this section.

3 Empirical Results

Since this work's aim is to explain the dynamic changes in the world trade from the network perspective, we firstly compute the average out-degree and in-degree centralities for developed and developing countries separately. De Benedictis et al. (2014) use a density measure for this purpose, which means the ratio of observed trade links to maximum possible trade links in the network. For the links indicating trade flows out and in, out-degree and in-degree centralities, we use these centralities separately to observe the difference between flows. We also divide data into developed and developing countries to see how different countries behave over time.

Fig. 1: Average out-degree centrality

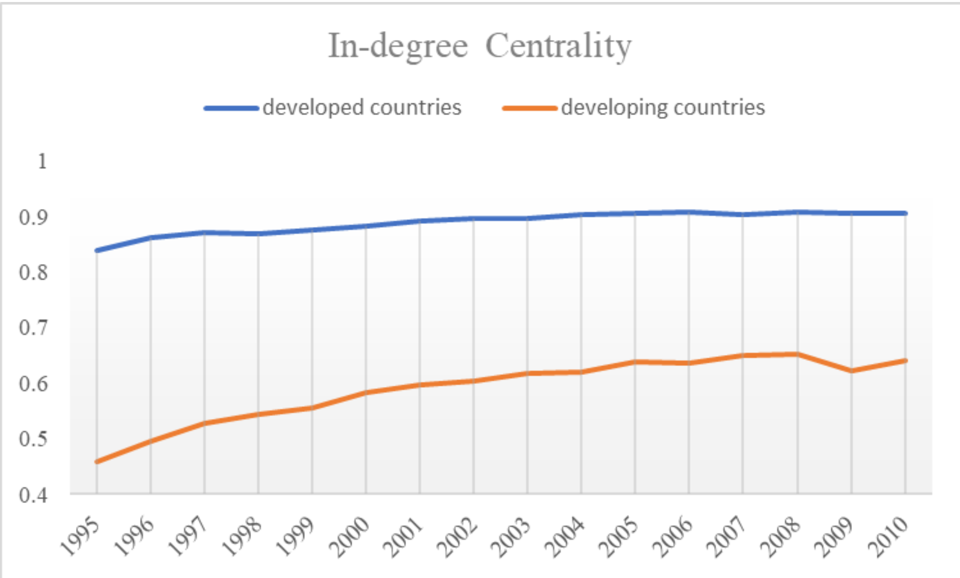


Source: Authors' calculations.

Fig. 1 shows 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. Since the latest global crisis, we observe a decline though.

As can be seen from Fig. 2, similarly, average in-degree centrality 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 higher degree centralities. Position of developed countries in the trade network is less affected from the 2008 crisis than that of developing countries is.

Fig. 2: Average in-degree centrality



Source: Authors' calculations.

We separate our analysis into two steps. Firstly, we perform the OLS regressions for all countries which are displayed in Tab. 2. 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. All of the four measures of centralities have significantly positive coefficients.

Tab. 2: Regression Results for All Countries

log trade volume	(1)	(2)	(3)	(4)
log weighted distance	-1.146***	-1.170***	-1.150***	-1.145***
	(-203.9)	(-206.4)	(-206.9)	(-203.4)

log GDP per capita (the origin)	0.976***	1.139***	0.845***	0.990***
	(268.0)	(391.7)	(209.4)	(274.2)
log GDP per capita (the destination)	0.916***	0.895***	0.925***	0.911***
	(322.7)	(313.6)	(328.7)	(321.0)
log population (the origin)	0.987***	1.171***	0.873***	1.003***
	(225.0)	(322.7)	(189.8)	(229.8)
log population (the destination)	1.021***	1.002***	1.027***	1.020***
	(283.6)	(276.3)	(288.1)	(283.1)
log area (the origin)	-0.0671***	-0.0941***	-0.0524***	-0.0714***
	(-23.68)	(-33.15)	(-18.64)	(-25.20)
log area (the destination)	-0.139***	-0.136***	-0.139***	-0.140***
	(-49.39)	(-47.91)	(-49.91)	(-49.76)
contiguity	1.233***	1.175***	1.243***	1.225***
	(43.37)	(40.94)	(44.16)	(43.06)
common currency dummy	0.848***	0.726***	0.787***	0.874***
	(24.38)	(20.66)	(22.86)	(25.09)
common language dummy	1.057***	0.982***	1.080***	1.054***
	(86.54)	(79.76)	(89.24)	(86.15)
GATT dummy (the origin)	0.0829***	0.329***	-0.0295**	0.135***
	(6.711)	(27.29)	(-2.405)	(11.05)
GATT dummy (the destination)	0.283***	0.278***	0.288***	0.300***
	(24.03)	(23.36)	(24.67)	(25.38)
log out-degree	1.387***			
	(74.32)			
log out-strength		0.0336***		
		(16.78)		
log out-closeness			4.488***	
			(103.6)	
log out-eigenvector				1.589***
				(69.41)
	6.745***	4.553***	8.458***	10.22***
Constant	(86.31)	(58.62)	(104.4)	(95.82)
Observations	265,154	265,154	265,154	265,154
R-squared	0.667	0.661	0.674	0.666

Source: Authors' calculations. t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

For the second step, we estimate our model for the two groups of countries with each four centrality measures. However, in Tab. 3, we only report the regressions for out-degree centrality measure due to the space considerations. The first column (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.

Tab. 3: Regression Results for Developing and Developed Countries

log trade volume	1-1	0-0	1-0	0-1
log weighted distance	-1.006***	-1.232***	-1.203***	-0.685***
	(-121.0)	(-133.3)	(-103.6)	(-45.20)
log GDP per capita (the origin)	0.893***	0.965***	1.180***	0.974***
	(81.99)	(153.4)	(107.1)	(124.3)
log GDP per capita (the destination)	0.827***	0.711***	0.879***	1.033***
	(79.87)	(131.3)	(167.9)	(76.24)
log population (the origin)	0.822***	0.926***	1.045***	0.982***
	(102.9)	(122.7)	(135.3)	(102.0)
log population (the destination)	0.780***	0.980***	1.015***	1.342***
	(120.7)	(170.3)	(181.7)	(161.6)
log area (the origin)	0.0191***	-0.0678***	-0.0947***	-0.0475***
	(3.394)	(-14.66)	(-18.03)	(-7.933)
log area (the destination)	0.0314***	-0.184***	-0.151***	-0.262***
	(5.590)	(-40.54)	(-33.83)	(-37.92)
contiguity	0.539***	1.430***	1.339***	2.389***
	(16.93)	(37.22)	(14.23)	(19.77)
common currency dummy	0.0912***	1.206***	0.872***	0.722*
	(3.478)	(23.28)	(2.705)	(1.750)
common language dummy	0.690***	0.864***	1.007***	1.246***
	(22.71)	(47.68)	(43.15)	(40.64)
GATT dummy (the origin)	0.0885*	0.173***	-0.385***	-0.271***
	(1.845)	(9.811)	(-6.916)	(-12.03)
GATT dummy (the destination)	0.292***	0.245***	0.0877***	-0.355***
	(7.394)	(14.22)	(5.318)	(-5.688)
log out-degree	1.189***	1.590***	2.664***	1.757***
	(11.45)	(52.21)	(23.21)	(50.44)
	5.527***	10.02***	6.378***	3.358***
Constant	(34.68)	(75.01)	(37.77)	(16.67)
Observations	19,036	126,861	61,250	58,007
R-squared	0.857	0.549	0.727	0.672

Source: Authors' calculations. t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Compared to the full sample regressions, we obtain very similar results for these four groups for the distance, GDP per capita, and the population. However, areas of the origin and the destination country now raise bilateral trade volumes when the flow is between developed 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 trade volumes except out-strength centrality when the flow is between developing to developed country. In this case, out-strength centrality has negative effect on bilateral trade.

Conclusion

In this study, gravity, network, and trade datasets from CEPII are combined, and then country-specific properties and network indices are used to explain the dynamic changes in the world trade network. We separate 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 trade volumes for all countries, and then for the flows between developed and developing countries.

When we look at the 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 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.

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