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Contents

Gravity Model and International Trade: the Case of OECD Countries

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KEY WORDS: Gravity model. International trade, Trade pattern, OECD, Transpost costs, GDP, Distance

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ABSTRACT - *This paper investigates relationship between trade variables such as exports and country's macro variables which is fully explained using gravity model of trade. Moreover, theoretical background of gravity model on international trade is explained in respect to change in transport costs. Gravity model approach is used in analysing trade pattern of the OECD countries in gravity equation ranging from 1990 to 2008. Empirical evidence of this work proves the expected signs of variables in gravity equation (GDP and Distance) mainly focusing on the role of transport costs in explaining variable Distance.*

Introduction

The purpose of this work is to assess the degree of impact of macro variables on the exports of OECD countries using gravity model of international trade. In the past fifteen years European countries have experienced substantial trade integration followed by the constitution of the European Union (Maastricht Treaty, 1993) and various PTA and RTA arrangements[2]. The existence of world trade policy incorporated in the GATT rules and the development of World Trade Organisation provided solid ground for trade liberalisation.

Due to the availability of data, set of analysed countries is narrowed to European OECD member countries[3]. European OECD member countries have increased their exports with the rest of the World from 137,4 billions $US in 1990 to 468,4 billions $US in 2007[4] (Table 1) which is mainly result of organic growth (new members) and lowering tarrif rates amoung the members in the European Union. Organic growth also boosted OECD's total economic strength measured by GDP (PPP) which increased from 8343,1 billions $US in 1990 to 12203,9 billions $US in 2007[5] (Table 2). This relationship between exports and gross domestic product is analysed thoroughly in empirical part of the study as well as other variable(s) in the model (e. g. Distance).

Bilateral trade flow between European OECD member countries and the rest of the World is analysed on a set of data from 1990 to 2008[6] at a yearly basis. Trade flow in this context is associated with exports of goods FOB. Exports serves as a dependent function in a modeling gravity equation using economic size of a country and particular distance between trade partners.

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[2] Such as CEFTA

[3] As of October 2008, OECD consists of 30 members in total (23 from Europe), mostly high income countries (see OECD brochure)

[4] Extracted from OECD Stats database (International Trade MEI)

[5] Extracted from OECD Stats database (GDP)

[6] Annually data not available for the year 2008 at the time of writing

Theoretical framework

In order to determine the pattern of international trade it is wise to remember contribution of theories that precedeed the development of gravity model. Classical theory of comparative advantages defined by David Ricardo (1817) was a milestone in researching how trade can be mutually beneficial for all trade partners due to the labour costs and difference in labour productivity. Introduction of Heckscher-Ohlin trade theory (1919) based on relative factor abundance and difference in relative factor prices has opened long-lasting academic debate about all causes and effects of trade. Refined version of Heckscher-Ohlin theory was made with FPE theorem (Samuelson, 1948, 1949), Heckscher-Ohlin-Vanek theorem and some empirical testing that were mostly rejecting idea of real existence of HO theory, notably Leontief for USA (1954) and Horvat (1968) for Yugoslav countries. Conclusions that arise from Heckscher-Ohlin theory of international trade will remain very important in the analysis of changes in output prices due to changes in transport costs.

The first formulation of gravity model based on Newton's Law of universal gravitation was made by Tinbergen (1962). Analogy with physics served perfectly as a logical explanation of trade flow between countries. Other authors like Armington (1969), Anderson (1979), Bergstrand (1985), Helpman and Krugman (1985) and Brun et. al. (2005) also gave their contribution to the extension of the model which will be discussed later on. Significant findings in the same area but for South-East Europe were presented by Vujčić and Šošić (2004) with special stress on trade potential of Croatia.

There are two major variables explaining bilateral trade flow between trade partners: economic strength of a country (variable GDP), and geographical proximity (variable Distance).

The functional form of the gravity model is given in Equation 1:

$$E_{ij} = A \cdot GDP_i^{\beta_1} \cdot GDP_j^{\beta_2} \cdot D_{ij}^{\beta_3} \qquad (1)$$

where
E = exports from country i to country j
A = constant
GDP = gross domestic product
D = distance

Better understanding of the gravity equation in terms of elasticity is achieved using log-linear structure (logarithmic values[7] of all variables) in Equation 2:

$$\log E_{ij} = \alpha_{ij} + \beta_1 \log GDP_i + \beta_2 \log GDP_j + \beta_3 \log D_{ij} \qquad (2)$$

Where β_1, β_2 and β_3 parameters are interpreted as coefficients of elasticity of exports in respect to changes in independent variables (GDP and distance). This change of dependent variable is not in absolute terms, it is rather relative change due to interpretation of log structure and percentage changes that persist in β_i coefficients.

[7] Natural logarithm used for the log values

Most often trade flow is calculated as arithmetic mean of exports and imports, but in this work dependent variable will be solely exports in order to emphasize the role of exports for analysed countries.

Equation 2 can also be extended using other variables that could possibly measure economic strength of a country better, such as Population (POP), *GDP per capita* (GDP/POP) or combination of all mentioned. Furthermore, the extended gravity equation can also be writen in the following form:

$$\log E_{ij} = \alpha_{ij} + \beta_1 \log GDP_i + \beta_2 \log GDP_j + \beta_3 \log POP_i + \beta_4 \log POP_j + \\ + \beta_5 \log\left(\frac{GDP_i}{POP_i}\right) + \beta_6 \log\left(\frac{GDP_j}{POP_j}\right) + \beta_7 \log D_{ij} \quad (3)$$

The idea of this paper is to test expected signs of β_1 and β_2 coefficients on GDP variables from Equation 2 using regression analysis which should comply with the signs from Table 3:

Table 3. Expected signs of β_i coefficients

β_i	Expected sign of β_i
β_1	+
β_2	+

Positive signs in Table 3 arise from the positive impact of higher income on imports of country's trade partner under constant marginal propensity to import. Greatest breakthrough in explaining GDP variable in gravity model was made by Armington (1968) and later on Bergstrand (1985). Their contribution involves introduction of price changes in form of GDP deflator and real exchange rates. Some recent findings by Bussière, Fidrmuc and Schnatz (2008) include FDI flows as an additional variable in the analysis. Results have shown positive sign for FDI but with lower elasticity (see Bussière et. al., 2005).

An impact of geographical proximity on trade is negative, and suggests that distance affects trade in the opposite way ($\frac{\partial E_{ij}}{\partial D_{ij}} < 0$) due to transport costs. Hence, the expected sign of parameter β_3 for variable Distance is negative ($\beta_3 < 0$).

How to measure distance is a key question in setting gravity model properly. One way is to use great circle[8] distance between capital cities of trade partners (country *i* and country *j*). The other way is to use auxiliary variables that represent changes in prices that occur in process of trade between countries *i* and *j*. These can be measured either using real exchange rate or the price of oil. The latter is chosen as a suitable representative of transport costs in empirical part of the study. Due to the mentioned transport costs[9] it is impossible to hold Heckscher-Ohlin's assumption that international trade will equalize prices of all tradeable goods in countries that participate in trade. Transport costs inhibit trade and discriminate prices in both trade partners as well.

[8] Using haversine formula from spherical trigonometry
[9] Also known as *border effects*

Parameter α_{ij} accounts for all other unobservable variables that are not explained directly through gravity equation and includes cultural, historical, political and language differences among countries.

Empirical results

The goal of empirical part of this paper is to implement linear regression analysis on a set of data for 23 European OECD countries in a time period between year 1990 and 2007. Dependent variable (response variable) in a model is „*Exports*" for OECD countries (EOECD) and independent variables (explanatory variables) are as follows: *„GDP OECD" (GDPOECD), „GDP World"* (GDPW) and variable „*Distance*" (D). Data for GDPs of trade partners are given in Appendix (see Table 2 and 4). Variable Distance uses OECD's crude oil import prices, CIF (US$ per barrel) – see Appendix (Table 5). All data are available annually, except for year 2008 which is excluded from an analysis.

Regression equation[10] with three predictors in log-linear form is given in Equation 4:

$$\log EOECD = \alpha_{OECD,W} + \beta_1 \log GDPOECD + \beta_2 \log GDPW + \beta_3 \log D_{OECD,W} \quad (4)$$

Logarithmic values of all (dependent and independent) variables with 5 decimal points precision are given in Table 6 and serve as input for computer support in regression calculation:

Table 6. Log values of all variables in regression analysis

t	LGEOECD	LGGDPOECD	LGGDPW	LGD
1990	4,92304	9,02919	9,99320	3,10433
1991	4,92122	9,04707	10,04170	2,95954
1992	4,97632	9,06111	10,10780	2,91497
1993	4,91456	9,06281	10,12288	2,79728
1994	5,05099	9,08627	10,19333	2,74962
1995	5,25282	9,11368	10,29780	2,84501
1996	5,30164	9,13435	10,31869	3,02071
1997	5,29110	9,16398	10,31539	2,95047
1998	5,32554	9,19298	10,30737	2,53244
1999	5,32706	9,21850	10,34257	2,84912
2000	5,37509	9,25807	10,37190	3,33200
2001	5,38477	9,27321	10,36470	3,15966
2002	5,44708	9,28734	10,40326	3,18335
2003	5,62362	9,30080	10,51930	3,34648
2004	5,79610	9,32856	10,63903	3,59315
2005	5,87788	9,35059	10,71561	3,92461
2006	6,00341	9,38175	10,79193	4,12319
2007	6,14931	9,40951	10,90315	4,23715

Source: World Bank, OECD Stats Database, author's calculation

Link between response variable and explanatory variables is shown in Table 7 using coefficients of linear correlation:

[10] Single country gravity model used

Table 7. Correlation matrix

	LGEOECD	LGGDPOECD	LGGDPW	LGD
LGEOECD	1,000000	0,958464	0,993864	0,866439
LGGDPOECD	0,958464	1,000000	0,951261	0,801894
LGGDPW	0,993864	0,951261	1,000000	0,856881
LGD	0,866439	0,801894	0,856881	1,000000

Source: Author's calculation

From Table 7 it is clear there is a high positive linear correlation between World's GDP and OECD's exports of goods ($\rho_{LGGDPW,LGEOECD} = 0,993864$). Demand for OECD's export products is almost perfectly correlated with the changes in World's GDP which arises from the similarity of trade structures of both trading partners according to Linder's (1967) hypothesis of international trade.

Results of regression analysis based on Equation 4 is presented in Table 8:

Table 8. Regression analysis on LGEOECD variable

Dependent Variable: LGEOECD				
Method: Least Squares				
Sample: 1990 2007				
Included observations: 18				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-11.14337	1.278928	-8.713061	0.0000
LGGDPOECD	0.444644	0.256987	1.730223	0.1056
LGGDPW	1.183458	0.144348	8.198642	0.0000
LGD	0.049191	0.039375	1.249307	0.2320
R-squared	0.990601	Mean dependent var		5.385642
Adjusted R-squared	0.988588	S.D. dependent var		0.376355
S.E. of regression	0.040206	Akaike info criterion		-3.396487
Sum squared resid	0.022631	Schwarz criterion		-3.198626
Log likelihood	34.56838	F-statistic		491.8663
Durbin-Watson stat	1.169291	Prob(F-statistic)		0.000000

Source: Author's calculation

Popularity of gravity model in explaining trade pattern is justified due to high R-squared (0,990601) which expresses goodness of fit between observed and predicted values.

Test statistics shows that only variable LGGDPW is significant in explaining variable LGEOECD under 5% significance level (N=18) on individual basis[11]. The same result can be shown using p-values. This is consistent with the fact that World's demand (measured by GDP) for OECD's goods is positively correlated, i.e. $\frac{\partial E_{OECD}}{\partial GDP_W} > 0$.

Group test (F statistics) shows the following results: with k=3 and N=18 critical value for F test with $\alpha = 0,05$ equals F(3,14)=3,34. Empirical value from Table 8 (F-statistics=491,8663) is

[11] Critical value in t-test is $t_{0,025} = 2,101$

higher than critical value (491,8663>3,34) which leads to conclusion that at least one variable is significant in explaining dependent variable LGEOECD in the model under $\alpha = 0{,}05$ significance level.

All expected signs from Table 3 (β_1 and β_2) are proven in regression output and, once again, it can be said that a rise in economic strength measured by GDP increases trade[12] between countries that participate in it.

Interpretation of β_i coefficients in log-linear form is in terms of elasticity due to log values used. Variable „Distance" doesn't conform with gravity model expectations and parameter's negative sign. This can be explained using real variables, in this case oil prices, instead of physical distance. β_3 coefficient interpreted as percentage change of OECD's exports in respect to changes in distance is closer to zero and doesn't affect trade significantly.

Conclusion

An importance of gravity model is undisputed in every serious analysis of international trade flows. The goal of this paper was to seek and find relationship between country's exports and economic power of its trading partners as well as distance. For this purpose dependent variable was presented through OECD's exports in time period between 1990 and 2007. Predicted variables for economic strength were presented with GDP (PPP) and distance was analysed through the changes in import prices of oil in OECD countries.

Expected parameters defined in theoretical gravity model assumed positive correlation between economic strength and exports of trading partners. This assumption was empirically tested and proven using t-test and F-test with positive signs of regression parameters assigned to GDP variables. Demand for OECD's export products is almost perfectly correlated with the changes in World's GDP which arises from the similarity of trade structures of both trading partners according to Linder's hypothesis of international trade. Low inelasticity of exports in respect to changes in transport costs (oil prices) was achieved according to regression output. Variable *„Distance"* didn't give expected parameter's value (negative) although its regression coefficient was close to zero.

Results of an empirical test conducted on a set of data for European OECD countries show that gravity model serves as a good explanation for trade flows and patterns of international trade.

[12] Defined as exports of one country to another

Appendix

Table 1. OECD Europe - Total Trade (in billions of $US), 1990 - 2007

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
OECD Europe	Exports in goods	137,4	137,2	144,9	136,3	156,2	191,1	200,7	198,6	205,5	205,8	216,0	218,1	232,1	276,9	329,0	357,1	404,8	468,4
	Imports in goods	142,1	144,5	150,7	134,7	152,0	184,3	193,3	191,8	202,2	203,8	218,7	214,2	223,4	270,0	324,4	357,1	408,0	474,5

Source: OECD Stats Database (2008) International Trade MEI [online].
Available at: http://stats.oecd.org/wbos/index.aspx [October, 21, 2008]

Table 2. OECD Europe – GDP (expenditure approach, in billions of $US), constant prices, constant PPPs, OECD base year, 1990 - 2007

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
OECD Europe	8.343,1	8.493,6	8.613,7	8.628,3	8.833,2	9.078,6	9.268,3	9.546,9	9.827,9	10.081,9	10.488,9	10.648,9	10.800,4	10.946,8	11.254,9	11.505,6	11.869,8	12.203,9

Source: OECD Stats Database (2008) GDP (expenditure approach) [online].
Available at: http://stats.oecd.org/wbos/index.aspx [October, 21, 2008]

Table 3. GDP World (current US$, in billions), 1990 - 2007

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
World GDP (current US$)	21.877,3	22.964,3	24.533,6	24.906,4	26.724,2	29.667,2	30.293,5	30.193,7	29.952,6	31.025,8	31.949,2	31.720,0	32.967,0	37.023,2	41.732,4	45.053,9	48.626,7	54.347,0

Source: World Bank (2008) World Development Indicators database (World GDP, current US$) [online].
Available at: http://ddp-ext.worldbank.org/ext/DDPQQ/report.do?method=showReport [November, 3, 2008]

Table 5. OECD crude oil import price, CIF, US$ per barrel, 1990 - 2007

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
OECD crude oil import price, CIF, USD per barrel	22,3	19,3	18,4	16,4	15,6	17,2	20,5	19,1	12,6	17,3	28,0	23,6	24,1	28,4	36,3	50,6	61,8	69,2

Source: OECD Stats Database (2008) OECD crude oil import price, CIF, US$ per barrel [online].
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