GRAVITY MODELING: INTERNATIONAL TRADE AND RD

Josheski, Dushko and Fotov, Risto

University Goce Delcev -Stip

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Dushko Josheski[1] (University Goce Delcev-Stip) **Risto Fotov**[2] (University Goce Delcev-Stip)

Abstract

In this paper issue of gravity modeling in international trade has been investigated. Standard gravity equation augmented with other variables to control for transportation cost, whether trade partners are neighbors and whether country is landlocked, or countries participants in trade have had colonial history together. Also in our model we control whether traded commodities are homogenous, differentiated or high tech, as well referenced. Variable to denote technology are: TAI index, which stands for technological achievement index, also variables for creation and diffusion of technology, as measured by the number of patents from the residents and royalty and license fees receipts, by the foreign citizens**.** Results are as expected and the show that trade is highly dependent on the exporters and importers levels of technology.

Key words: bilateral trade, gravity model, R&D, OLS, PPML

[1] Teaching Assistant, Ph.D. student, "Goce Delcev" University, Stip, R. Macedonia, dusko.josevski@ugd.edu.mk
[2] Professor, Faculty of Economics/Department Finance, "Goce Delcev" University, Stip, R. Macedonia, risto.fotov@ugd.edu.mk

Introduction

The gravity model has long been recognized for its robustness in explaining many types of international flows, including international trade flows, migration, and others (Pöyhönen, 1963[3],; Bergstrand, 1985). In the gravity model there exists analogy between gravitational attraction between two bodies being determined by their mass and distance between them, bilateral trade flows are essentially to be determined by the national incomes of the exporting and the importing countries (economic mass), the distance between them. Analogy with physics is given with the following equation $GF = A\frac{M_1 M_2}{D^2}$.

Theoretical foundations of this model are in the general equilibrium model of supply and import demand. Assumptions to hold this general equilibrium model is, homogenous goods (perfect substitutes).

$$Q^d = f(p, d_1, d_2, ..., d_n)$$
$$Q^s = f(p, s_1, s_2, ..., s_m) \qquad (1)$$

Here Q^d depends on the price and other factors on the side of the demand, while the supply behaves on a similar way. In this system of perfect substitutes, demand and supply of homogenous goods depends on the demand and supply factors, but not on the prices. This is due to the fact that the prices of perfect substitutes are the same in all countries. Prices are endogenous and adjust continuously to equate supply and the demand. This also explains why the gravity modeling data are averaged over several years. Prices temporary may be high, when system is in disequilibrium, so this suggest the use of averaged data in order to assure the relevance of the results (Leamer and Stern, 1970). Otherwise, the gravity model is very successful in the empirical literature and has been justified theoretically by Leamer and Stern, (1970), Anderson (1979)[4].

[3] Pöyhönen, P. (1963) ***A Tentative Model for the Volume of Trade between Countries***, *Weltwirtschaftliches Archiv*, 90(1), 93-100.

[4] Anderson, J.A ***Theoretical Foundation for the Gravity Equation***, *American Economic Review* (63) (March 1979), 106-16.

Theoretical link between innovations and trade

Small open economies have higher marginal utility from openness to trade, than large economies[5].Second, trade also gives incentive for knowledge spillovers, from developed to less developed economies. Helpman and Coe (1995)[6], find that foreign R&D have positive effect on the domestic economy, and that this effect increase with the increase in openness of the economy. Helpman and Coe (1995), estimate the following model;

$$\log TFP_i = a_i^0 + a_i^d \log R\&D_i^d + a_i^f m_i \log R\&D_i^f \quad (2)$$

Here TFP is total factor productivity, R&D^d, are domestic innovations, R&D^f, are foreign innovations. Third, trade liberalization increases the market competitiveness and make domestic firms to innovate more. Final good production in the two countries is assumed to be symmetrical

$$Y_t^* = \int_0^1 Y_{it}^* di = (L^*)^{1-a} \int_0^1 \hat{A}_{it}^{1-a} \left(x_{it}^*\right)^a di, \qquad 0 < a < 1$$

$$Y_t = \int_0^1 Y_{it} di = L^{1-a} \int_0^1 \hat{A}_{it}^{1-a} x_{it}^a di, \qquad 0 < a < 1 \qquad (3)$$

The production function with asterisk is foreign country GDP, and without asterisk is domestic country. Or if we simplify output will be $Y_t = \left(\hat{A}_{it}^{1-a} x_{it}^a\right) L^{1-a}$, price by which monopolist sells the good is a partial derivative of the previous equation, marginal product of the output $p = {}^{\partial Y_t}\!/_{\partial x_t} = \alpha(\hat{A}_{it} L)^{1-\alpha} * x_t^{\alpha-1}$.Or if we rearrange for the intermediate input we get $x_{it} = \hat{A}_{it} L (p_{it} / a)^{\frac{1}{a-1}}$, if we measure trade intensity of the domestic economy with foreign trade partners with θ^*, and with θ we measure just the openness of the economy. Than differential equation is:

$$\frac{dA}{dt} = -bA + (\theta * \theta)^{\sigma} * v^{\psi} \left(\frac{A^*}{A}\right)^{\varepsilon} \qquad (4)$$

[5] Alesina, A.,Spolaore,E.,Wacziarg,R.,(1997),Economic integration and politic disintegration, NBER working paper

[6] Coe and Helpman (1995), "International R&D Spillovers" European Economic Review, 39 (5): 859-887

Here b is the technology parameter $v = \frac{K(t)}{Y(t)}$ and the parameter $\psi = \frac{\frac{dk}{dt}}{I}$, actually v^{ψ} are per capita investment in R&D,σ is the elasticity of substitution. And if we define $h' = (\theta * \theta)^{\sigma} * v^{\psi}$ differential equation can be presented as $\frac{\partial A(t)}{\partial t} = (h' * A(t)^{\varepsilon}) * A(t)^{-\varepsilon} - bA(t)$, or the solution of this differential equation is given as $A(t) = C_1 * e^{-bt} + \frac{h'}{b}$. In such a case technology will not be a factor of convergence to steady-state , but openness and trade intensity. Rivera,Batiz,Romer (1991)[7], introduce human capital in to the equation

$$Y(H_Y, L, x) = H_Y^{\alpha} L^{\beta} \int_0^{\infty} x(i)^{1-\alpha-\beta} \, di \qquad (5)$$

Here H, denotes human capital, while L is labor used in production of technologies. Growth of technology (innovations) is given with the expression $\frac{\dot{A}}{A} = \varphi * H_A$.

Data and methodology

Here we use data for 13 exporting countries, bilateral trade data are derived from Feenstra (2005)[8], the sample of countries derives from 13 exporters USA,Australia, Japan, Brazil, Bolivia,Chile, China, Czech Republic, Germany, Spain, UK, Ghana and South Africa, and 77 importer countries[9]. We use the data that are present at the centre for International trade data at UC Davis[10]. And Jon Haveman's international trade data web page. Mostly observations are derived from Laura Marquez Ramos paper which is cited in the footnote.World development indicators (2005), are used for derivations of incomes, tariffs are derived from World integrated trade solution (WITS), and Doing business (2006) for transportation costs. Distance between cities and colonial dummies are taken from Jon Haveman's international trade data web page[11].The contiguity data are from this web site also. And the common language variable is

[7] Rivera-Batiz and P. Romer (1991), "***International Trade with Endogenous Technical Change***." European Economic Review, 35: 971-1004.

[8] Feenstra, R. C., Lipsey, R. E., Deng, H., Ma, A. C. and Mo, H. (2005), "**World Trade Flows, 1962-2000**". NBER-United Nations Trade Data, NBER Working Paper No. 11040.

[9] Laura Márquez-Ramos; Inmaculada Martínez-Zarzoso, 2010, "**The Effect of Technological Innovation on International Trade. A Nonlinear Approach**[Dataset]",http://hdl.handle.net/1902.1/14520 Economics: The Open-Access, Open-Assessment E-Journal [Distributor] V1 [Version]

[10] http://cid.econ.ucdavis.edu/

[11] http://www.macalester.edu/research/economics/page/haveman/Trade.Resources/Data/Gravity/dist.txt

derived from the international trade data web. TAI index technological achievement index is constructed by the creation of new technology, and diffusion of the new technology variable. The technology and innovations in one country are captured, by the number of patents of the residents in the country and the royalty fees and receipts from abroad. The TAI index categorizes the countries in four groups ,technological leaders (TAI>0.5),Potential leaders (0.35<TAI<0.49),Dynamic adopters(0.19<TAI<0.34),and marginalized (TAI<0.19), Laura Marquez Ramos et all.(2010).From the estimation techniques we use in our modelations OLS , Instrumental variable estimation (IV), and PPML –Pseudo Poisson Maximum likelihood models, that used to control for heteroscedasticity. In the poison model β coefficient is interpreted as semi elasticity $\frac{\partial \log E(Y_i \mathrm{I} x_i)}{\partial x_{i1}} = \beta_1$.

Specifications

In the international trade, bilateral trade flows are usually explained by the following specification:

$$PX_{ij} = \beta_0 (Y_i)^{\beta_1} (Y_j)^{\beta_2} (D_{ij})^{\beta_3} (A_{ij})^{\beta_4} u_{ij}$$
$$\text{or, in log - linear form for OLS estimation}$$
$$\ln PX_{ij} = \beta_0 + \beta_1 Y_i + \beta_2 Y_j + \beta_3 D_{ij} + \beta_4 A_{ij} + u_{ij} \quad (6)$$

Where

- PX_{ij} is the U.S. dollar value of the flow from country *i* to country j,
- β_0 is the constant term;
- Y_i (Y_j) is the U.S. dollar value of nominal GDP in *i* (j),
- D_{ij} is the distance from the economic centre of *i* to that of j,
- A_{ij} is any other factor(s) either aiding or resisting trade between i and j, and
- u_{ij} is a log-normally distributed error term with $E(\ln u_{ij}) = 0$.

In our model also captured are transportation costs for the exporter and the importer, technological achievement index of the exporter and the importer, which has been used by the UNDP, to measure how well a country is diffusing and creating technology, and also human skills. Equation (1) is commonly supplemented by an "adjacency dummy" for a common land border. A_{ij} typically includes dummy variables for trade associations, which commonly are best available proxy for trade policy

(See Bergstrand, 1985, p.478)[12].

This variables also exists in our model. 'This specification was used in Tinbergen (1962), Pöyhönen (1963), Pullainnen (1963), Geraci and Prewo (1977), Prewo (1978), and Abrams (1980)', (Bergstrand, 1985).Our augmented specification will be presented in the flowing equation, our model also includes dummy variables by the Rauch classification (1999)[13],that is coding goods as , referenced, homogenous and differentiated. In the OLS equation we also use human capital variable, this variable is as proxy for the skills that workers have in exporter's countries and importer countries. Also there is dummy variable, whether countries that participate in the trade are members of North American free trade association (NAFTA), or other countries, or dummy variable that takes value 1 if countries are members of Andean community. Also dummy that controls whether countries participants in trade had colonial history together. And dummy whether countries are landlocked. Also variables are used to control for the diffusion of technology by the importer and exporter, and creation of the new technology by the importer and the exporter. Also dummy for high tech products is constructed, to test how high tech products influence trade.

$$PX_{ij} = \beta_0 + \beta_1 Y_i + \beta_2 Y_j + \beta_3 D_{ij} + \beta_4 Adj_{ij} + \beta_4 Land_i + \beta_5 land_j + \beta_6 NAFTA + \beta_7 CAN + \beta_8 Lang\_off + \beta_9 TAI_i + \beta_{10} TAI_j + \beta_{11} Tarrifs_{ij} + \beta_{12} tc_i + \beta_{13} tc_j + \beta_{14} high\_tech + \beta_{15} homogenousprod_k + \beta_{16} ref_k + \beta_{17} differentiated + \beta_{18} heteropgeneity + u_{ij} \quad (7)$$

tc denotes for transportation costs, from country *i* to country *j*, heterogeneity is dummy variable that controls for country heterogeneity, dummy variable that takes value of one when participants in trade are richer than the average sample. Homogenous, differentiated, and high-tech as well referenced products, refer to Rauch (1999), classification of products.

Results

Results from the estimations are reported in the tables below. In the first table are reported three models, OLS, IV and Poisson model. Than in the following table 2 IV model with creation of technology variable, and a model with a diffusion of technology. In the last table it is shown the effects of homogenous, differentiated, and referenced goods on international trade flows by OLS and PPML model.

[12] Bergstrand, J. (1985) ,***The Gravity Equation in International Trade***, Review of Economics and Statistics, 67(3), 474-81

[13] http://www.macalester.edu/research/economics/page/haveman/Trade.Resources/TradeData.html

Table 1 OLS model IV model and Poisson model

	OLS model		IV model		Poison model	
Dependent variable :Bilateral trade	Coefficient	pvalue	Coefficient	pvalue	Coefficient	pvalue
Technological innovation in the exporting country (R&D investment)	-	-	2.21	0.000	-	-
Technological innovation in the importing country(R&D investment)	-	-	1.65	0.000	-	-
Income in the exporter country	0.911	0.000	0.54	0.000	0.045	0.000
Income in the importer country	0.797	0.000	0.83	0.000	0.054	0.000
Exporters transportation cost	0.834	0.000	-0.99	0.000	0.002	0.600
Importers transportation cost	-0.651	0.000	-0.77	0.000	-0.045	0.000
Distance	-0.950	0.000	-0.72	0.000	-0.051	0.000
Tariffs	0.020	0.008	0.00	0.742	0.000	0.692
Official common language	0.683	0.000	0.34	0.000	0.034	0.000
Dummy variable = 1 when commodity is a high-technology commodity, 0 otherwise	-0.047	0.000	-0.07	0.000	-0.004	0.000
Dummy variable = 1 when a commodity k is homogeneous, according to Rauch classification (1999), 0 otherwise	0.067	0.000	0.13	0.000	0.006	0.000
Dummy variable = 1 when a commodity k is reference-priced, according to Rauch classification (1999), 0 otherwise	0.005	0.6	0.03	0.002	0.001	0.105
Dummy variable it takes the value of 1 when trading partners are richer than the sample average	0 .21	0.000	0.28	0.000	0.004	0.000
Exporter's human capital	-8.805	0.000	-	-	0.086	0.000
Exporter's human capital squared	7.621	0.000	-	-	0.115	0.000
Importer's human capital	1.592	0.000	-	-	-0.040	0.000
Importer's human capital squared	-1.134	0.000	-	-	0.096	0.000
Dummy variable it takes 1 if countries are members of North American free trade association	0.864	0.000	0.29	0.000	-0.205	0.000
Dummy variable it takes 1 if countries are from Andean community	0 .019	0.638	-	-	-0.034	0.000
It takes value 1 if trading countries are neighbors	0.943	0.000	1.10	0.000	0.012	0.000
It takes value 1 when importing country is landlocked	-1.791	0.000	-1.55	0.000	0.589	0.000
It takes value 1 when exporting country is landlocked	-0.062	0.000	-0.35	0.000	0.045	0.000
It takes value 1 if trading countries have had colonial history together	0.352	0.000	0.17	0.000	0.054	0.000
Constant	-23.945	0.000	-7.39	0.000	0.002	0.600
R squared and Pseudo Rsquared for Poisson model	0.79		0.79		0.0529	
Number of observations	57272		46440		58387	

From the first three models exporters transportation costs are positively and statistically significant in all three model , importers transportation cost have negative sign and they are statistically significant. Income in the exporters and importers country is positively related to the bilateral trade flows, importers human capital is positively related to trade, and exporter's human capital is negatively correlated with bilateral trade flows. Distance is negatively highly associated with trade -0.950, and p value (0.000), in the OLS model while -0.045 and pvalue 0.000 in the PPML model. High technology products are negatively associated with trade , -0.067 and pvalue 0.000, if a country participant in trade is a member of NAFTA coefficient of elasticity of bilateral trade flows is high 0.864 , and significant at all levels of significance. If the trading partners are neighboring countries coefficient is very large and positive 0.943 and highly statistically significant, pvalue is 0.000. If importing country is landlocked coefficient of elasticity is -1.791, and highly significant. And if exporting country is landlocked coefficient is -0.062 and highly statistically significant. And if trading countries have had colonial history, coefficient is positive and statistically significant 0.352. Coefficient in the IV model and PPML model are similar in size and in sign. There is exception in Exporters human capital which in OLS model is negative but in PPML model is positive but of small size 0.086 and statistically significant at all levels of significance. And also importers human capital is positive and statistically significant in the OLS model, but negative and of small size in the PPML model -0.040. This coefficient is also highly statistically significant. Tariffs in our model are positively and statistically significantly correlated with the bilateral trade flows, which is take as rather unexpected result. If trading partners are members of Andean community, dummy variable coefficient is positive and statistically significant, which is true also if trading countries are richer than average of the sample, i.e. if there is heterogeneity in the trade. And if homogenous products are trade coefficient on the bilateral trade elasticity is positive and statistically significant 0067, and if products are referenced according to Rauch (1999), classification also the coefficient is positive and statistically significant. On the next table model is augmented with the creation of technology as explanatory variable.

Table 2 IV model with creation of technology variable as explanatory variable

	OLS model	
Dependent variable :Bilateral trade	Coefficient	pvalue
Exporter creation of technology	3.67	0.16
Importers creation of technology	0.31	0.06
Income in the exporter country	0.23	0.02
Income in the importer country	0.93	0.00
Exporters transportation cost	-2.00	0.08
Importers transportation cost	-0.93	0.01
Distance	-0.75	0.01
Tariffs	-0.03	0.01
Official common language	0.48	0.02
Dummy variable = 1 when commodity is a high-technology commodity, 0 otherwise	-0.06	0.01
Dummy variable = 1 when a commodity k is homogeneous, according to Rauch classification (1999), 0 otherwise	0.12	0.02
Dummy variable = 1 when a commodity k is reference-priced, according to Rauch classification (1999), 0 otherwise	0.03	0.01
Dummy variable it takes the value of 1 when trading partners are richer than the sample average	0.64	0.02
Dummy variable it takes 1 if countries are members of North American free trade association	3.67	0.16
It takes value 1 if trading countries are neighbors	0.19	0.06
It takes value 1 when importing country is landlocked	1.15	0.04
It takes value 1 when exporting country is landlocked	(omitted)	n.a.
It takes value 1 if trading countries have had colonial history together	-0.17	0.02
Constant	-0.12	0.02
R squared	0.76	
Number of observations	50600	

In this model signs of the variables are expected same as in the previous model which we interpreted, exporters and importers cost have negative sign, while importers and exporters income has positive elasticity with bilateral trade, Tariffs here as expected are negatively related with trade flows, exporters creation of technology is positively associated with bilateral trade 3.67, and importers creation of new technology is positive 0.31 and statistically significant. In the next Table we present augmented model with diffusion of technology.

Table 3 Diffusion of a new technology model

	OLS model	
Dependent variable :Bilateral trade	Coefficient	pvalue
Diffusion of recent technology by exporting country	3.668	0.000
Diffusion of recent technology by importing country	0.307	0.000
Income in the exporter country	0.234	0.000
Income in the importer country	0.934	0.000
Exporters transportation cost	-1.997	0.000
Importers transportation cost	-0.928	0.000
Distance	-0.746	0.000
Tariffs	-0.031	0.000
Official common language	0.485	0.000
Dummy variable it takes the value of 1 when trading partners are richer than the sample average	-0.064	0.000
Dummy variable it takes 1 if countries are members of North American free trade association	0.120	0.000
It takes value 1 if trading countries are neighbors	0.032	0.005
It takes value 1 when importing country is landlocked	0.644	0.000
It takes value 1 when exporting country is landlocked	0.188	0.001
It takes value 1 if trading countries have had colonial history together	1.147	0.000
Constant	7.463	0.000
R squared	0.77	
Number of observations	40204	

In this model signs of the variables are expected same as in the previous model which we interpreted, exporters and importers cost have negative sign, while importers and exporters income has positive elasticity with bilateral trade, Tariffs here as expected are negatively related with trade flows, exporters capability for diffusion of technology is positively associated with bilateral trade 3.67, and ability for diffusion of new technology is positive 0.307 and statistically significant. In the next Table we present augmented model with referenced products, differentiated products, homogenous products, and their influence on bilateral trade flows.

Table 4 Referenced products, differentiated products, and homogenous products

Types of products	**Referenced products**				**Differentiated products**				**Homogenous products**			
Models	**OLS model**		**Poisson model**		**OLS model**		**Poisson model**		**OLS model**		**Poisson model**	
Dependent variable :Bilateral trade	**Coef.**	**pvalue**	**Coef**	**pvalue**	**Coef**	**pvalue**	**Coef**	**pvalue**	**Coef**	**pvalue**	**Coeff**	**pvalue**
Technological innovation in the exporting country (R&D investment)	4.82	0.000	0.34	0.00	4.82	0.000	0.34	0.000	4.9	0.000	0.345	0.000
Technological innovation in the importing country(R&D investment)	2.92	0.000	0.21	0.00	2.91	0.000	0.21	0.000	2.92	0.000	0.206	0.000
Dummy variable = 1 when a commodity k is reference-priced, , 0 otherwise	0.09	0.000	0.01	0.01	-	-	-	-	-	-	-	-
Dummy variable = 1 when a commodity k is differentiated, 0 otherwise	-	-	-	-	-0.110	0.000	-0.01	0.00	-	-	-	-
Dummy variable = 1 when a commodity k is homogenous, 0 otherwise	-	-	-	-	-	-	-	-	0.120	0.000	0.008	0.060
Constant	10.92	0	2.42	0	11.03	0.00	2.42	0.00	10.94	0	2.417	0
R squared and pseudo R squared for the poisson regression		0.36	0.0239		0.359		0.0239		0.3587		0.0239	
Number of observations		67365	67365		67365		67365		67365		67365	

TAI index in all 6 models is positive and statistically significant , importers TAI and exporters TAI share common sign (+).Referenced priced products has positive and statistically significant sign when regressed with bilateral trade flows, on the other side trade with differentiated products is negatively associated with the bilateral trade. And homogenous products have expected positive sign in association with bilateral trade.

Conclusion

Gravity model once again proved to be useful technique, when we study international trade bilateral trade flows. As in the theory we proved that innovations are highly associated with trade and also for policy makers important conclusion is that they must enhance trade with investment in R&D. Innovations are trade promoting variable in our findings. Government consumption is negatively associated with growth usually, but fiscal policy can enhance promotion of R&D and therefore to promote exports for the country where this policy has been applied. From the regression results also the greatest impediment for international trade are: the distance between countries, importers transportation costs, and if trading partners are landlocked.

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