International Journal of Business and Management Study - IJBMS
Volume 3 : Issue 1 *[ISSN 2372-3955]*
Publication Date : 18 April, 2016

Panel data PPML approach to the gravity model

The case of Visegrad countries export

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***Abstract*— The paper presents the use of the augmented gravity model for panel data. Silva and Tenreyro (2006) showed that the formerly used Hausman-Taylor estimator fails to provide consistent estimates in this class of models. They propose the use of Poisson pseudo maximum likelihood (PPML) approach, that consists in solving a set of first order condition equations that stem from the Poisson regression model but are applied to attain estimates in the log-linear regression. We expand their results by including random country effects in the model, which allows for the more efficient use of country-level panel data. We use the above described model to estimate the effects of a couple of factors on the value of exports of the group of Visegrad countries (V-4, Visegrad four). These include the EU accession and the recent economic crisis, as well as other countries' characteristics typically included in the gravity models. We allow for structural breaks and check whether the moment of joining the EU could be considered as one. The results assessed for the group of the EU countries trading with 234 countries of the world in the 1999-2013 period demonstrate the beneficial effects of the EU membership as well as the existence of structural break at the moment of the EU enlargement. The robustness checks confirm validity of the proposed estimation approach.**

***Keywords*— European integration, gravity model, international trade, Visegrad group, PPML**

I. Introduction

The EU enlargement has quite a long history associated with the important treaties and agreements implications of which have become the most actual and considerable issues for economic research. The cooperation within the Visegrad Group (V-4) postulated in the Visegrad Declaration dates back to 1991, preceding the closure of the Council for Mutual Economic Assistance and the withdrawal of Soviet troops from the region. Aiming the creation of the regional stability, the declaration emphasized the importance of internal changes, democratization and liberalization of the economies involved.

It is remarkable, that although economic and commercial cooperation between V-4 was not included among the goals of declaration, negotiations on concluding a free trade area started already in 1991. Finaly, Central European Free Trade Agreement (CEFTA) was ratified by individual countries in 1994, being considered as an important step towards the integration of V-4 on the way to their joining the European Communities (EC).

Our paper examines whether the EU accession was beneficial for trade performances of the V-4. We construct the augmented gravity model for the panel data of the exports of the EU member states to the rest of the world consisting of 234 countries in 1999-2014. Our model controls for both: the impacts of Common Commercial Policy (CCP) and natural trade partners of V-4. While the former involves the adoption of the common external tariffs together with regional trade agreements (RTAs) of the EU, the latter controls for the former Soviet member states among trade partners. Finally we employ Poisson and PPML estimators with and without inclusion of country specific individual effects to provide estimations. We set the structural break in 2004, thus the parameters are allowed to differ across the two time periods:1999-2003 and 2004-2013. Estimation results demonstrate that integration within the EU was quite beneficial for all NMS including V-4.

II. The model

The most popular methodologies to study the impacts of international trade on economies of countries involved in the process of regional integration is the theoretical framework of the Gravity model (Soloaga and Winters 2001, Ghosh and Yamarik 2004, Carrere 2006, Silva and Tenreyro 2006, Baier and Bergstand 2009, Magee, 2008, Acharya et al. 2011). The model was introduced by the crucial work of Jan Tinbergen (1962) based on a law called the "gravity equation" by analogy with the Newtonian theory of gravitation reflecting the relationship between the size of economies, the amount of their trade and the distance between the trade partners, in the following form:

$$X_{ij} = GS_j M_j \emptyset_{ij} \quad (1)$$

where X_{ij} is the monetary value of exports from i to j, M_j controls for all importer-specific factors that make up the total importer's demand and S_j comprises exporter-specific factors that represent the total amount exporters are willing to supply. G is an independent variable from i and j, such as the level of world liberalization. Finally, $\emptyset_{ij}$ represents the trade costs between i and j countries. The latter is mainly represented as the country-pair-specific information such as contiguity and distance, common language, ethnic groups or borders, common memberships in regional trade agreements and tariff rates between trade partners.

Although the gravity model is already a commonly accepted and a standard tool to study the trade flows, the specification of the equation for estimation purposes differs

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according to the approaches of different authors. The most remarkably, Silva and Tenreyro (2006) in their seminal paper have raised a problem that has been ignored so far by both the theoretical and applied studies. In particular they argued, that the logarithmic transformation of the original model is not relevant approach to estimate elasticities. Namely, the multiplicative trade models with multiplicative error do not satisfy the assumption of the homoscedasticity of the error term since there is dependency between the error term of transformed log-linear model and the regressors, which finally causes inconsistency of the ordinary least squares estimator or the random and fixed effects estimator unless very specific (and highly improbable) conditions are fulfilled.

Let

$$EX_{ij} = \beta_0 \cdot Y_i^{\beta_1} \cdot Y_j^{\beta_2} \cdot diffGDP_{ij}^{\beta_3} \cdot Z_{ij,1}^{\beta_{4,1}} \cdot \cdot \ldots \cdot Z_{ij,k}^{\beta_{4,k}} \cdot \exp(D_{ij}'\beta_5) \cdot \varepsilon_{ij} \quad (2)$$

be the gravity equation of interest for the case of cross-section in certain period *t* where EX_{ij} is the export flows from country *i* to country *j*, Y_i and Y_j represent the current GDPs of the trade partners, $diffGDP_{ij}$ is equal to $|Y'_i - Y'_j|$ and stands for the absolute value of the difference between the real GDP per capita of the importer and exporter countries respectively, $Z_{ij,1}$ up to $Z_{ij,k}$ are the k non-binary variables that contain the information on the reporter-partner pair (such as distance between the trade partners), while D_{ij} are the *l* dummy variables that carry information on the pair and its economic surrounding (such as contiguity which equals one when the trade partners share the common border and zero otherwise;, time dummy for the financial crisis which equals 1 if the year is 2009;, several dummies standing for the RTAs, such as the FTA, CU, EIA, which equal one if both trade partners are sides of a particular RTA and zero otherwise and dummies denoting the EU15, NMS, V-4 and the former states of the Soviet-Union among trade partners. The ε_ij represents the pair-level error term, while all the betas are the structural parameters (or their vectors) of the models.

Silva and Tenreyro (2006) provide a profound explanation why the typically applied solution that consists in taking the logarithms of both hand sides of (1) and then estimating the resulting equation with some form of a linear least squares estimator is statistically incorrect and leads to inconsistent estimates. Furthermore, it should be noticed that the procedure of logarithmization enforces either dropping all the pairs with zero trade (due to the inexistence of the logarithm of zero) or applying certain not-fully-true solution (such as incrementing the value of export in each pair by certain low value in order to achieve positive export values that could be logarithmized in each case). While the first solution is a form of non-random subsample selection (usually the distant and small countries are dropped from the estimation sample), the second changes the structure of the model which does not fit the theoretical assumptions anymore. Instead, they propose a different procedure.

Notice that under the assumption of

$$E\left(\varepsilon_{ij} \middle| Y_i, Y_j, diffGDP_{ij}, Z_{ij,1}, \ldots, Z_{ij,k}, D_{ij}\right) = 1 \quad (3)$$

which essentially includes assuming the first moment of ε_{ij} to be independent from the explanatory variables in the equation, the (1) can be written as

$$E[EX_{ij} | Y_i, Y_j, diffGDP_{ij}, Z_{ij,1}, \ldots, Z_{ij,k}, D_{ij}) = \\ = \beta_0 Y_i^{\beta_1} Y_j^{\beta_2} diffGDP_{ij}^{\beta_3} \cdot Z_{ij,1}^{\beta_{4,1}} \cdot \ldots \cdot Z_{ij,k}^{\beta_{4,k}} \exp(D_{ij}'\beta_5)] = \\ = \exp(ln\,\beta_0 + \beta_1 lnY_i + \beta_2 lnY_j + \beta_3 lndiffGDP_{ij} + \\ + \beta_{4,1} lnZ_{ij,1} + \cdots + \beta_{4,k} lnZ_{ij,k} + D_{ij}'\beta_5). \quad (4)$$

Further denote $A(x_{ij})$ as:

$$A(x_{ij}) = ln\beta_0 + \beta_1 lnY_i + \beta_2 lnY_j + \\ + \beta_3 lndiffGDP_{ij} + \beta_{4,1} lnZ_{ij,1} + \cdots + \beta_{4,k} lnZ_{ij,k} + D_{ij}'\beta_5,$$

where x_{ij} is the (column) vector of the transformed variables as in the right hand side of (4), that is

$$x_{ij} = [1 \;\; lnY_i \;\; lnY_j \;\; lndiffGDP_{ij} \;\; lnZ_{ij,1} \;\ldots\; lnZ_{ij,k} \;\; D_{ij}']' \quad (5)$$

Silva and Tenreyro (2006) propose to find the estimates of equation (2) by solving the set of first order condition equations:

$$\sum_{ij}(EX_{ij} - \exp A(x_{ij}))\, x_{ij} = 0. \quad (6)$$

Besides tackling with the zero export flows in the data, the authors demonstrate that the estimator based on the above mentioned equation shall generally be more efficient than the competitive nonlinear least squares one, while the efficiency benefits depend on the assumption of the conditional variance of EX_{ij} being proportional to its expected value. Should the latter not hold, the estimator remains consistent, but it could be made more efficient if the proper ration of the conditional variance to conditional mean is considered. Additionally, the set of first order conditions in this case is exactly the same as in the case of the Poisson regression model and solving (6) would be equivalent to finding the maximum likelihood estimator in the Poisson regression though without assuming the Poisson conditional distribution (or even integrity) of the exports. Thus the above can be viewed as the Poisson pseudo-maximum likelihood estimator.

Taking into account that the data of the export flows of the EU and V-4 to the rest of the world for the time period 1999-2014, present the panel character. In the simplest case that converts model (2) into

$$EX_{ijt} = \beta_0 \cdot Y_{it}^{\beta_1} \cdot Y_{jt}^{\beta_2} \cdot diffGDP_{ijt}^{\beta_3} \cdot \cdot Z_{ijt,1}^{\beta_{4,1}} \cdot \ldots \cdot Z_{ijt,k}^{\beta_{4,k}} \cdot \exp(D_{ijt}'\beta_5) \cdot \varepsilon_{ijt}, \quad (7)$$

where *t* denotes a particular year. Obviously, some of the variables might remain time invariant (such as the dummy for common border). However, the above model is extended in two ways.

Firstly, we allow for structural change in 2004 since we believe that the EU enlargement might have changed the influence of independent variables on the levels of exports. Technically this can be done in two ways: either by estimating (7) separately for the period 1999-2003 and 2004-2013 or by introducing a set of interaction terms of the independent variables with a dummy variable which

distinguishes between the two considered time spans (1999-2003 and 2004-2013). The latter is better: first, we can get a single model with a higher number of degrees of freedom and second, by employing the Wald statistics we can easily test whether the parameter of each independent variable exhibited a statistically significant change since 2004.

Secondly, the above approach neglects the fact that the data are indeed of panel character. Quite the opposite: in such a case the data are actually treated as a stream of cross-sectional observations. Should we believe in the individual and distinct character of each pair of countries, individual effects should be introduced into equation (7), yielding:

$$EX_{ijt} = \beta_0 \cdot Y_{it}^{\beta_1} \cdot Y_{jt}^{\beta_2} \cdot diffGDP_{ijt}^{\beta_3} \cdot \cdot Z_{ijt,1}^{\beta_{4,1}} \cdot \ldots \cdot Z_{ijt,k}^{\beta_{4,k}} \cdot \exp(D'_{ijt}\beta_5) \cdot \alpha_{ij} \cdot \varepsilon_{ijt} \quad (8)$$

where α_{ij} represents the time constant individual effect of pair *ij*. We adopt the random effects approach as the fixed effects approach seems inappropriate: first of all the number of periods is too low to treat it as anywhere "near infinity" which would yield the incidental parameters problem in the fixed effects case. An additional drawback of the fixed effects approach would be that any time invariant regressors would be dropped, as well as the pairs of never-trading countries. The random effects approach , on the other hand, has a different disadvantage: it requires the assumption regarding the distribution of the individual effects and, first of all, it requires that – similarly to (2) for the error term – the distribution of the individual effects to be independent of the regressors. However, certain expected value of the individual effects needs to be assumed for identification reasons. We thus make the typical assumption of individual effects being distributed gamma with an expected value of one.

III. Data and results

The data on the export flows in millions of Euros come from the Eurostat. The data of the current GDP levels in millions and real per capita GDPs are included from the World Development Indicators database complied by the World Bank. The data for the other variables such as distance and contiguity are taken from the CEPII database and the data for the regional agreement memberships come from the World Trade Organization (WTO). According to the data availability, the sample covers the period from 1999 to 2013. The considered group of countries consists of all the 28 EU members as exporters, while as importers together with the EU countries, we take the rest of the world consisting of 234 countries in our sample. The complete set of variables included in the model is given in Table 1.

Additionally, as we have described in the previous section, in our estiation equation (2) we introduce an interaction of the independent variable by including a dummy variable which splits the time period into two parts - the pre- and post-EU admission periods. Estimation results are given in table 2. These include the parameter estimates, their robust standard errors and p-values for the significance test. Each of the above is provided separately for the pre- (the first three columns) and the post-accession period (the last three columns).

TABLE I. VARIABLES USED IN THE ANALYSIS

Variable	Definition	Source	Exp. Sign
exports	Exports in millions of Euros (dependent variable)	Eurostat	
lXGDP	Natural logarith of GDP in current US dollars of a reporter country	WDI	+
lMGDP	Natural logarithm of GDP in current US dollars of a partner country	WDI	+
ldiffGDP	Natural logarith of the absolute value of difference of GDP per capita in purchasing power parity (PPP) of reporter and partner countries	WDI	-
ldistance	Natural logarithm of geographical distance between the capital of the trading partners	CEPII	-
contig	Dummy variable standing for the neighboring countries	CEPII	+
EU15_par	Dummy variable denoting the EU15 countries among partners	-	+
NMS_no_VIS	Dummy variable denoting new member states of the EU among partners, excluding Visegrad countries	-	+
VIS_par	Dummy variable denoting V-4 among partners	-	+
Post_Sov	Dummy variable denoting the former Soviet states	-	?
RTAs	Dummy variable standing for the all three types of signed RTAs with trade partners excluding the EU members	WTO	+
crisis	Dummy variable indicating year 2009	-	-

Source: own compliation.

As Table 2 indicates, GDP of both the exporter and importer countries for V-4 yield the positive and statistically significant impacts on the exports at the 1% significance level both before as well as after 2004. The change in the impacts of GDP that took place in 2004 is significant but only at the 10% level for both the EU15 and V-4. Absolute difference in the GDP per capita enters with the negative sign as expected, however, only for the pre-EU accession period. We may argue that since joining the EU, CCP of the EU reflected in the new generation trade agreements reduced the impacts of the difference of economic development between V-4 and their trade partners. Overall, our findings are in line with the literature of the gravity model. However, quite surprisingly, the estimates of the parameters standing for the influence of distance and contiguity have no significant impact on the export performances of V-4.

TABLE II. ESTIMATION RESULTS

variable	Until 2003			From 2004 on		
	estimate	std. error	p-value	estimate	std. error	p-value
lXGDP	0,662	0,070	0,000	0,718	0,044	0,000
lMGDP	0,814	0,082	0,000	0,829	0,086	0,000
ldiffGDP	0,155	0,081	0,055	0,007	0,058	0,908
ldistance	-1,180	0,226	0,000	-1,130	0,193	0,000
contig	0,429	0,218	0,049	0,410	0,186	0,027
EU15_par	0,238	0,377	0,528	0,336	0,435	0,440
NMS_no_VIS	0,877	0,563	0,119	0,838	0,650	0,198
VIS_par	0,549	0,554	0,322	0,717	0,673	0,287
Post_Sov	0,788	0,363	0,030	0,500	0,331	0,131
RTAs	-0,014	0,183	0,939	0,211	0,209	0,312
crisis	-	-	-	-0,140	0,014	0,000
constant	-12,01	2,697	0,000	-12,01	2,697	0,000

Source: own calculations, Stata (2013).

The dummy variables standing for regionalism, are msotyl found to be insignificant with the only exception of the dummy standing for post-soviet countries. The later turns out to be statistically significant in the pre-accession period. This finding indicates that by joining the EU, the V-4 has changed the direction of their export flows from the post-Soviet countries to the other trading partners.

The estimate of the parameter of the crisis dummy enters with the negative sign as expected highlighting that the recent economic crisis had quite negative effects on the export performances of V-4.

IV. Conclusions

The paper aimed to investigate geographical structure of exports of the V-4 before and after the EU enlargement. Based on the augmented gravity model, we estimated the panel data of the export flows of the V-4 over 1999-2013. Together with the standard gravity variables, we have included the set of dummy variables denoting the regionalism of the EU15 and V-4 countries. To illustrate the outcomes of the EU accession of V-4 on their export performances we introduced the time interactions which allowed to assume the country time invariant individual effects to remain the same for the whole period of analyses. We followed the advancement in the empirical trade literature and applied the poison approach to deliver estimation results. However, unlike to the previous studies, we employed the poison estimator for the panel data. The latter allowed us to keep the country characteristics in the estimations and therefore to deliver the plausible estimates.

Estimation results revealed that the EU accession of the V-4 was beneficial on their export performances however on an expanse of the trading with the post-Soviet countries.

Acknowledgments

The authors of the article gratefully acknowledge financing by the National Science Centre of Poland, project number UMO-2013/11/B/HS4/01040.

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