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## MULTILEVEL MODELLING OF BILATERAL TRADE FLOWS BETWEEN EUROPEAN UNION COUNTRIES

### 1. INTRODUCTION

The gravity model of international trade flows has been widely used by econometricians since Tinbergen (1962) published the first gravity equation that describes bilateral trade as directly proportional to the mass of two trading countries, namely, their national incomes, and as inversely proportional to the distance that separates them, which should approximate trade costs<sup>1</sup>. A popular way to approximate the trade costs, included in the theoretical gravity model proposed by Anderson, van Wincoop (2003), is the use of physical distance and a set of different dummies in the model such as, for instance, a common border, a common official language, access to the sea or sharing a trade agreement. However, the theoretical form also requires the inclusion of multilateral trade-resistance (MTR) terms, which could be approximated by the use of time dummies together with invariant country dummies (Eaton, Kortum, 2002; Helpman, 2006) or by the use of time-varying country effects in the model<sup>2</sup> (Baldwin, Taglioni, 2006), by the use of a simulation method with the inclusion of the elasticity of substitution<sup>3</sup> (Anderson, van Wincoop, 2003; Baier, Bergstrand, 2009) or by constructing the time invariant or time-varying synthetic variables, called remoteness<sup>4</sup> (Wei, 2000). The omission of MTR terms that are correlated with trade costs leads to the bias in the estimates (Ruiz, Villarubia, 2007, p. 18).

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<sup>1</sup> Transportation-, information-, communication costs, technical barriers to trade (TBTs), etc.

<sup>2</sup> However, the disadvantage of this method is the inability to estimate the coefficients on country-specific variables, such as national income or population, due to perfect collinearity.

<sup>3</sup> There is no consensus in the subject literature concerning the exact value of this parameter. Generally, the elasticity of substitution is assumed to fall in the range from 5 to 10 (Anderson, van Wincoop, 2004).

<sup>4</sup> Explaining the role of remoteness, Deardoff (1998) considers two pairs of countries,  $(i, j)$  and  $(k, l)$ , and assumes that the distance between these countries in each pair is the same:  $D_{ij} = D_{kl}$ . If  $i$  and  $j$  are closer to other countries, the more remote countries,  $k$  and  $l$ , will tend to trade more between each other because they do not have alternative trading partners. The definition of Deardoff's remoteness probably inspired Anderson, van Wincoop to apply MTR terms (2003).

Due to the heterogeneity that occurs by modelling international trade flows, the FE estimator is frequently applied while conducting research (Egger, 2000; Green *et al.*, 2001; Cheng, Wall, 2005; Pietrzak, Łapińska, 2014), since it improves the panel model by including fixed effects for every trading pair in the sample, which can be easily seen on the coordinate system in the plane as a set of parallel multiple regression equations<sup>5</sup>. The use of the FE estimator was also indicated as a better way of the approximation of MTR terms in the author's previous work devoted to the issue of alternative methods of implementing and estimating multilateral trade resistance in the panel gravity model of bilateral trade (Drzewoszewska, 2014). However, this solution ignores the average variation between trading pairs, which Egger (2000) and Cheng, Wall (2005) consider in the context of historical, political and geographical factors. Another disadvantage of the FE estimator is the fact that all the variables that are constant over time will be dropped by the estimation due to collinearity with fixed effects. On the other hand, however, the estimation of individual regressions may face sample problems and lack of generalization. Moreover, the FE estimator is inconsistent (with fixed  $T$ ,  $N \rightarrow \infty$ ) without the conditional strict exogeneity assumption and becomes inefficient when the number of clusters is high. Due to Beck, Katz (2001) submission, it would be interesting to model the differences in the basic level of trade, across trading partners, and to allow heterogeneous slopes as well. The use of mixed effects model in this study allows certain coefficients of the gravity model to vary across trading country pairs, which leads to an output where a set of regression for every trading pair is not parallel any more. According to Gelman, Hill (2007) multilevel methods generally allow consistent and efficient estimation.

The 3-level model presented in the study assumes random slope for incomes' product and the intercept in three groups: when the bilateral trade flows between old EMU-members<sup>6</sup> (intra-EMU trade), between old and new members or non-EMU members (inter-EMU trade) and between new and/or non-members of euro-area (outside EMU trade). The random slope at level 2 (between trading pairs) is the product of national incomes of both countries (the denominator of the basic gravity equation that reflects the combined size of the two trading countries) and their common internetization rate – the share of internet users in the whole population of both trading countries, which reflects the quality of the network infrastructure of a specific trading pair. The study assumes three research hypotheses. According to the first one, the more both trading countries are globalized, which is indicated by higher values of the globalization factors in the gravity model, the more intensive the bilateral trade

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<sup>5</sup> Other popular estimation methods for gravity panel models which are more complex than simple pooled model include the Poisson pseudo maximum likelihood (PPML) estimator for the dependent variable at the levels proposed by Santos Silva, Tenreyro (2006) as an alternative for NLS, tobit model for panel data (Soloaga, Winters, 2001; Baldwin, DiNino, 2006; Tripathi, Leitão, 2013), HT estimator (Serlenga, Shin, 2004; Belke, Spies, 2008; Drzewoszewska, Pietrzak, Wilk, 2012) or probit – with Heckman's approach (Linders, de Groot, 2006; Martin, Pham, 2008).

<sup>6</sup> The old EMU-members are understood here as the first countries that created the union in 1999.

exchange between them becomes. Following the second hypothesis, the Eurozone causes the pure trade creation effect (bilateral trade flows increase if both exchange partners are members of the EMU) with no trade diversion effect<sup>7</sup>. The third hypothesis assumes that the bilateral flows between two European countries rise with the probability that both of them are able to communicate in English – the world's *lingua franca*. The first part of the paper presents some extensions of the gravity model's form in the empirical research. The second part describes the methodology of an empirical multilevel model and the outcome of the research conducted.

## 2. EMPIRICAL RESEARCH OF TRADE FLOWS WITH THE APPLICATION OF THE GRAVITY MODEL

Empirical investigation of the border puzzle effect on the inter and intra-trade was the inspiration for Anderson, van Wincoop (2003, 2004) to create their theoretical structural gravity model. Namely, they continued the research of McCallum (1995), who analysed the implication of trade patterns between Canadian provinces and U.S. states with the result that bilateral Canadian provinces' trade is 22 times more intensive than the exchange with U.S. states. After the introduction of MTR terms to the model, with the assumption that the elasticity of substitution  $\sigma = 8$ , Anderson, van Wincoop (2003) decomposed the border effect into the impact border barriers and multilateral resistance effects. Finally they found that Canadian provinces trade 10.7 times more than provinces with states due to the existing country border. That was the result of including MRT terms in the model, the omission of which is the crucial factor for the biased estimation of the border effect.

The gravity model of trade became a popular tool for analysing the effects of trade liberalization (McCallum, 1995) or common currency on trade (Rose, 2000). Investigating the trade or monetary union effects leads to the problem of endogeneity – due to 'natural trading partners' hypothesis<sup>8</sup>. However, the implication of dummies describing the RTA is still a common procedure, since it allows for analysing the trade creation and trade diversion effects of the agreement (Kandogan, 2005). The details are described in a further part of this study.

When investigating the EMU effects, there arises also the question whether the EMU is close to the optimum currency area. According to the idea of the optimum

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<sup>7</sup> The analysed trade diversion effects indicate the reallocation of imports from the most/less efficient source on the global market to more inefficient/efficient sources within the Eurozone. Since all EU members in the sample have reached a similar level of economic development, the expected trade diversion effects are insignificant.

<sup>8</sup> In the panel model the use of FE can help to overcome part of the endogeneity problem due to the omitted variable bias, although time-varying omitted variables remain a problem. Among another possible ways to estimate such a gravity model the popular method is IV estimation with instruments, namely Hausman-Taylor estimator, which uses exogenous time-varying regressors  $X_{it}$  (from periods other than the current one) as instruments.

currency area (OCA) described by Mundell (1961), openness to capital mobility and price, and wage flexibility across the region are expected. The reason is that the market forces of supply and demand automatically distribute capital and goods to where they are needed. However, in practice this does not work perfectly as there is no true wage flexibility. According to the study of Baldwin (2006), the 'euro effect' suggests that the single currency has increased trade by 5 to 15 percent in the Eurozone with comparison to the trade between non-euro countries. In order to find out whether the growth of intra-Eurozone trade is greater than international EMU trade the dummy variables can be used to describe the participation in EMU (Micco *et al.*, 2002, 2003).

Most of the research conducted on the gravity model of trade considers only the influence of the official common language, finding that sharing language translates into greater trade intensity (Glick, Rose, 2002; Santos Silva, Tenreyro, 2006; or Baldwin, Taglioni, 2006). However, international commerce is increasingly conducted in English, even if neither side of the transaction is from an English speaking country. Hence, Melitz (2008) used Ethnologue database and proposed additional variables describing all indigenous or established languages spoken in the country, taking into account also the fraction of the population speaking those languages. He found that 'open-circuit' languages (those that are official or are spoken by at least 20% of the population in both countries; measured as dummy variables) and 'direct-communication' languages (those that are spoken by at least 4% of population in both countries; measured as 'communicative probability' that two randomly chosen individuals from both countries can communicate directly in any direct-communication language) increase bilateral trade. However, the limitation of Ethnologue database is that it investigates only native speakers or ethnic-minority populations (primary speakers). The analysis of Melitz (2008) showed that 'direct-communication' is about three times more effective than indirect-communication in promoting trade, and taking them both into account, the impact of a common language becomes nearly twice as high as in the traditional gravity model. Additionally, the English language seems to have no particular advantage in foreign trade (insignificant and even a negative sign of estimates), opposite to the European languages (German, French and Spanish) as a whole.

The next step in the languages' influence on bilateral trade flows – the approach proposed by Fidrmuc, Fidrmuc (2009) – was based on the results of Eurobarometer surveys on Europeans' ability to speak various languages<sup>9</sup>, which were carried out at the end of 2005. Here the consideration of both primary and secondary speakers is possible. Eurobarometer surveys are nationally representative what allows to estimate the share of each country's population that speaks each of 32 investigated languages<sup>10</sup> and finally, the probabilities that two randomly chosen individuals from two different

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<sup>9</sup> Eurobarometer 243, *Europeans and Their Languages*, European Commission, 2005.

<sup>10</sup> In the final estimations the authors focused on the measurement of the effect of languages spoken by at least 10% of the population in at least three countries – what yielded English, German, French and Russian.

countries will be able to communicate ('communicative probability'). The authors created the gravity model of trade for all members and candidates countries of the EU in the time period 2001–2007. After including two additional sets of indicators on bilateral language relationships in the model estimated with OLS and 2SLS methods, they found that the command of English raises trade flows in the area of EU15, as it does between the new members and candidates countries. The results obtained for other languages were varied. In fact, the effects of the languages investigated were non-linear, displaying diminishing returns<sup>11</sup>, which was shown by the authors with the application of the quantile regression. The results showed a hump-shaped effect on trade flows with the peak on the communicative probability in English which equals 70% for the countries with relatively higher trade intensity.

### 3. MULTILEVEL GRAVITY MODELS OF BILATERAL TRADE FLOWS – METHODOLOGY AND RESULTS OF THE RESEARCH

The mixed effects models described by Pinheiro, Bates (2000) are also known as random coefficients models (Longford, 1993) or multilevel models (Goldstein, 1995). A special case is the hierarchical linear model. This term was used first by Lindley and Smith (1972). The observations are made on units at different levels in a hierarchy. Statistical data are often multilevel (hierarchical, nested or clustered) in the sense that lower-level units of analysis belong to higher-level units of analysis. The panel data are multilevel as well – years are nested<sup>12</sup> within given countries. Multilevel models account for the dependence (clustering or correlation) found in hierarchical data. In the opposite, single-level models ignore this dependency and, therefore, may result in drawing wrong research conclusions, because of underestimated standard errors of the effects of covariates, too narrow confidence intervals, or incorrect statistical inferences (*i.e.*, Type 1 errors)<sup>13</sup>.

Export flows from the same country are typically more alike than flows from different countries, even if the importing country is the same, because of a unique relation connecting two trading countries. Moreover, export flows from the same year could also be more alike than flows from other year, because of the global economic condition. The use of mixed models in the analysis of bilateral trade flows allows a relatively broader investigation of relationships that connect different trading pairs of countries, as they assume a more complex error structure. The variables that move relatively slowly over time play a role in determining the average levels of trade between two trading partners. Additionally, the model captures unspecified hetero-

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<sup>11</sup> The return was particularly high for the countries with a relatively low level of proficiency in languages.

<sup>12</sup> It means that the random effects shared within lower-level subgroups are unique to the upper-level groups.

<sup>13</sup> See Rabe-Hesketh, Skrondal (2012).

geneity by allowing the intercept and certain slope coefficients of the model to have a stochastic component in their variation. In this study both three- and two-level hierarchical linear models are used to capture these effects, since years are nested within trading pairs, which are nested within the places of trade. Here the random effects at different levels are assumed to be uncorrelated. Each lower level residual is allowed-to-vary random departure from the higher-level departure. The error terms and random intercept are assumed to be normally distributed with the mean 0 and variances  $\sigma_{v0}^2$ ,  $\sigma_{u0}^2$  and  $\sigma_e^2$ , and to be mutually independent. The methodology used in the study is precisely described in the subject literature, see, for instance, Goldstein (1995), Osborne (2000), Raudenbush, Bryk (2002).

The economic integration of countries with free trade, free capital mobility and uncontrolled migration is the base for the globalization process (see Daly, 1999), which was the criterion for selecting certain EU countries to be included in the research sample (apart from Malta and Cyprus). The research time period (1999–2011) was chosen also based on the globalization theory – namely, the starting year is referred to by Friedman (1999) as ‘the year of the Internet’, opening a new era of easy outsourcing, offshoring and other new activities, leading to changes in the global trade structure.

The independent variables in the gravity model of trade can be easily divided for masses and the distance-variables (reflecting the trade costs)<sup>14</sup>. The first part should increase the trade flows between two countries, as it captures the wealth of trading partners, the second has a negative influence on trade, as it increases the trade costs. Considering the distance as the remoteness or the degree of countries’ similarity, the relatively more similar countries should have larger bilateral trade flows. Thus, according to the idea of globalization, more globalized countries should trade more between each other. Therefore, the estimated gravity models of bilateral export flows include, additionally to typical gravity model’s forces, a set of globalization factors which describes the distance of the country from the global markets. Among these variables the most important is access to the broadband Internet for country citizens, that reduces telecommunication costs for trading partners. The creation of the ‘New Economy’ in the world is observed by the increasing number of researchers in R&D, who are engaged in the conception or development of new knowledge, products, processes, methods or systems, and by the increase of high-technology exports products. The estimated models also contain two variables for this phenomenon: the calculated researchers rate for both trading partners and share of exporter’s high-technology export in his total export value. The set of the data used is described in Table 1.

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<sup>14</sup> The use of time effects in the gravity model reflects the variables that do not depend on  $o$  and  $d$ , such as the level of World liberalization and other global economic effects. According to the Isaac Newton’s law of universal gravitation, we can call it the gravitational constant.



Table 1.

Variables included in the analysis of international bilateral trade flows

Variable	Definition	Measure unit	Source
EXPORT	Export flows from origin country to destination country	USD (current prices)	Comtrade/OECD
GNIproduct	The product of both countries Gross National Incomes <sup>1</sup>	USD (current prices)	WDI
Travel	Travel time by road between the national centroids <sup>2</sup>	hour	Google Maps
Internetization	Common internetization rate (the share of internet users in the population of both trading countries)	share in %	Author's calculation / WDI
Researchers	Common researchers rate in R&D (the share of researchers in the populations of both trading countries)	share in %	Author's calculation / WDI
HighTechExport	Share of high-technology export in the total export of exporter	share in %	WDI
EnergyUse	The sum of energy use in both trading countries	kt of oil equivalent	Author's calculation / WDI
ExEMU	1 if the exporter belongs to The Economic and Monetary Union but the importer does not and 0 otherwise	dummy variable	
ImEMU	1 if the importer belongs to The Economic and Monetary Union but the exporter does not and 0 otherwise	dummy variable	
BothEMU	1 if both of the trading countries in the pair are members of The Economic and Monetary Union and 0 otherwise	dummy variable	
Border	1 if two trading countries share a common border and 0 otherwise	dummy variable <sup>3</sup>	
Sea	1 if at least one from two trading countries is not landlocked and 0 otherwise	dummy variable	
OfficialLanguage	1 if two trading countries share a common language and 0 otherwise	dummy variable	
Language Proficiency	1 if the language is official in both countries or spoken by more than 20% of populations and 0 otherwise	dummy variable	Author's calculation / Eurobarometer surveys
Language Communication	Probability that two trading partners will be able to communicate in the certain language	probability	Author's calculation / Eurobarometer surveys

<sup>1</sup> The use in the study GNI instead of GDP variable is intentional, as it measures income received by a country both domestically and from overseas.

<sup>2</sup> Great circle distance algorithm was used in the calculation.

<sup>3</sup> The formula to compute the effect of dummy-variables is following:  $(e^{b_i} - 1) \times 100\%$ , where  $b_i$  is the estimated coefficient.

Source: author's compilation.

The quality of infrastructure, another globalization indicator (Liberska, 2002, pp. 34-37), is included in the model through inclusion of the energy use of both trading countries which should lead to an increase in their trade, especially in the trade of commodities that is the subject of this study, and through the use of the travel time by road between trading countries (as an alternative to physical distance) by construction the synthetic variable of bilateral trade costs<sup>15</sup> (see equations 1–2). The bilateral trade costs  $t_{t,od}$  formula is following:

$$t_{t,od} = \frac{DISTANCE_{od}}{IMPORTER'S\_OPENNESS_{t,od}}, \quad (1)$$

where:

$$IMPORTER'S\_OPENNESS_{t,od} = \frac{EXPORT_{t,od} + EXPORT_{t,do}}{TOTAL\_IMPORT_{t,d}}. \quad (2)$$

This approach allows a substantive advantage of the bilateral trade costs-variable, namely making it time-varying in this approach, what suits better to reality, since trade costs are not constant over time. The distance between countries in formula (1) is measured by travel time between the centroids of trading countries<sup>16</sup> and is divided by the share of bilateral trade exchange in the total import of the importing country, called here as importer's openness (2). This method reflects the theoretical significance of the importer's demand in the final amount of bilateral trade flows.

The creation of the 'global community' advances with the easiness of communication between people that can be approximated by their language proficiency. Hence, the second important issue in the extension of the variables of the model is the language effects. According to the last Eurobarometer survey – 'Europeans and their Languages', published in June 2012 – the update on result from 2005<sup>17</sup> – English dominates as the language that Europeans are most likely to be able to speak. The linguistic map of Europe is similar to that presented in 2005 – the five most widely spoken foreign languages remain English (38%), French (12%), German (11%), Spanish (7%) and Russian (5%). The survey registered a slight drop in the

<sup>15</sup> The synthetic variable of bilateral costs was proposed and described in the author's previous work.

<sup>16</sup> The use of the travel time between countries' centroids became possible owing to free Google Maps application, which time-data was downloaded on 14.03.2014 (with the use of a special software for calculating distances between items from the list of locations that was ordered and sponsored by JLU Giessen).

<sup>17</sup> These nationally representative surveys investigated the language skills: the mother tongues and up to three other languages that they speak well enough to have a conversation. Source: *Special Eurobarometer 386*.



proportions able to hold a conversation in German and French (-3 and -2 percentage points respectively). The citizens of the ‘Old EU members’ (EU15) are particularly more likely than those in NMS12 to speak French (14% vs. 6% respectively) and Spanish (8% vs. 2%). Moreover, they are particularly less likely to speak German (10% vs. 15%) and Russian (2% vs. 16%). The most significant conclusion of European Commission’s surveys is that Europeans have very positive attitudes towards multilingualism and their passive skills are increasing. However, the results show that language skills are unevenly distributed both over the geographical area of Europe and over socio-demographic groups. The measurement of Europeans’ ability to speak various languages is an important stringency of the analysis for international trade flows, hence, the approach in this paper uses the results of both Eurobarometer surveys<sup>18</sup>, with the calculations following those in the study of Fidrmuc, Fidrmuc (2009). Namely, the factor of language is investigated in two ways. Firstly, three official languages, which are most widely spoken in Europe: English, German and French, are measured using dummies, if they are official in both countries or spoken by more than 20% of populations<sup>19</sup>. Secondly, the average proficiency rates  $\omega^{20}$  are used to estimate probabilities  $P_{f,od}$  that two randomly chosen individuals from countries  $o$  and  $d$  will be able to communicate in a certain language  $f$ :

$$P_{f,od} = \omega_{f,o} \cdot \omega_{f,d}. \quad (3)$$

In the above approach there is no distinction between whether the individuals are native speakers of the language or whether one or both of them speak it as foreign language. The coefficients of all the languages-variables are expected to be positive since they facilitate communication and ease trade transactions.

In fact, the investigation of the language effects is focused on the case of English. It is expected that the effect of English proficiency will be the strongest and positive. English plays actually a role of the *lingua franca*, it is the most widely spoken foreign language in the World. Trade relations between remote countries, for example, between Portuguese and Polish entrepreneurs are more likely to be facilitated by English than by Portuguese or Polish. In the empirical analyses of bilateral trade flows of Fidrmuc, Fidrmuc (2009) the English effect appeared robust to alternative regression

<sup>18</sup> The study uses the English proficiency that was calculated based on *Eurobarometer*, as an alternative to the EF English Proficiency Index, which has been criticized for its lack of representative sampling in each country – the respondents are self-selected and must possess access to the Internet.

<sup>19</sup> The results from the first Eurobarometer survey (*Eurobarometer 243*) are used to calculate the proficiency rates for the period of 1999–2005, the results from the second one (*Eurobarometer 386*) are used to reflect the proficiency rates for the time period 2006–2011.

<sup>20</sup> Proficiency rate  $\omega$  is the share of the population speaking the language as native speakers or speaking it as foreign language with ‘good’ or ‘very good’ level. Those indicators were taken from *Special Eurobarometer 243*, as the next survey does not contain the information about the level of proficiency.

specifications (also to inclusion of other languages in the analysis) and also here are expected to have significant and positive impact on trade.

In order to investigate trade creation and trade diversion effects of the Economic and Monetary Union the following three binary variables were included in the estimated model: *BothEMU*, *ExEMU*, *ImEMU* (Viner, 1950). The first one takes a value of 1 if both countries  $o$  and  $d$  belong to the EMU and zero otherwise. A positive and statistically significant coefficient of *BothEMU* represents trade creation effects and indicates that intra-regional trade has been promoted more by the free trade agreement and is higher than normal trade levels. In the EMU area, trade flows between countries are expected to increase with the time due to a more intense integration (not only political, but also cultural). *ExEMU* takes a value of one if exporter  $o$  belongs to the EMU and destination country  $d$  does not and zero otherwise. A positive and statistically significant coefficient of *ExEMU* is interpreted as an export diversion effect of the EMU and indicates that regional integration leads to a switch of export activities from EMU members to non-EMU members. *ImEMU* takes a value of one if exporter  $o$  is a non-EMU member and destination country  $d$  belongs to the EMU and zero otherwise. Its positive and statistically significant coefficient indicates an import diversion effect in EMU – then EMU members have shifted their importing activities from non-member countries to member countries. The specification of trade creation and trade diversion in the logarithmic form of gravity model can be written as follows:

$$EX_{t,od} = EV_{t,od} + \sum_t \phi_1 \text{BothEMU}_{t,od} + \sum_t \phi_2 \text{ExEMU}_{t,od} + \sum_t \phi_3 \text{ImEMU}_{t,od}, \quad (4)$$

where:  $EX_{t,od}$  – export flows,  $EV_{t,od}$  – the rest of explanatory variables. The coefficient  $\phi_1$  measures the extent to which trade is higher than normal levels if both countries are EMU-members,  $\phi_2$  measures the extent to which members' exports are higher than normal levels from non-member countries and  $\phi_3$  the members' imports effects respectively.

According to Martínez-Zarzoso *et al.* (2009), one observation alone of intra-bloc trade ( $\phi_1$ ) is insufficient to confirm whether or not there is a net trade creation in the free trade area – for instance, an increase in intra-bloc exports ( $\phi_1 > 0$ ) may be accompanied by reduction in imports from extra-bloc countries ( $\phi_3 < 0$ ). These trade creation and diversion effects may offset each other and hence, besides the coefficient of *BothEMU* variable, there is still the need of examination the magnitudes and directions of trade among member and non-member countries ( $\phi_2, \phi_3$ ). Assuming that  $\phi_1, \phi_2 > 0$ , which denotes that trade creation is accompanied by an increase in exports from intra-bloc countries to extra-bloc countries, this can be described as a pure trade creation in the EMU. However, a positive  $\phi_1$  accompanied by a negative  $\phi_2$  denotes a combination of trade creation effects and export diversion effects. Here, if  $\phi_1 > \phi_2$ , then, despite the trade creation effects are offset to a certain extent by export diversion

effects, the trade creation still dominates. In the case of  $\phi_1 < 0 < \phi_2$  a dominant export diversion effect representing a welfare loss on behalf of member countries<sup>21</sup>. In the case of decrease in intra-EMU export flows ( $\phi_1 < 0$ ), along with a higher propensity to imports ( $\phi_3 > 0$ ), occurs the extra-EMU import expansion.

According to the traditional gravity model, the trade flows are proportional to the product of national incomes and are divided by the distance between them. In this form only the distance is a variable (here bilateral trade costs variable) that is measured at the level of a trading pair of countries – the national incomes concern the countries which are at a higher level. However, putting the variable of the product of both incomes in the gravity model of trade is a common method as well (Sohn, 2005; Rahman, 2010; Gul, Yasin, 2011)<sup>22</sup> because it does not change the idea of the model and allows some estimation problems to be avoided, such as, for instance, the impossibility of the estimation of the countries' incomes effects if there are time-varying country effects used in the estimated model. Besides, the product of national incomes becomes a trading pair-level variable, which is especially helpful in the case of the multilevel modelling, where the pairs of countries compose the second level of the model. Most of the other variables are also established at the trading pair-level, namely the calculated internetization rate, researchers rate, energy use and variables describing communication in different languages. Only the share of the high-technology export remains at the country level.

In the 3-level model the random effects at different levels are assumed to be uncorrelated. Each lower level residual is allowed-to-vary random departure from the higher-level departure. For simplicity, the explanation of the form of estimated models is shown at the 2-level at first. With the above described set of covariates, the algebraic specification of random-coefficients 2-level model of bilateral trade is as follows<sup>23</sup>:

$$EX_{t,od} = \beta_{0,od} + \beta_{1,od}GNIproduct_{t,od} + \beta_{2,od}Internetization_{t,od} + \varepsilon_{t,od}, \quad (5)$$

with the fixed part of the model of:

$$\begin{aligned} \beta_{0,od} = & \beta_0 + \alpha_1BTC_{t,od} + \alpha_2 Research_{t,od} + \alpha_3 EnergyUse_{t,od} + \alpha_4 HighTechEx_{t,od} \\ & + \alpha_p D_{p,t,od} + \alpha_s P_{s,f,od} + \gamma_1 I_o + \gamma_2 I_d + \gamma_3 I_t + u_{0,od}, \end{aligned} \quad (6)$$

and the random part of the model:

<sup>21</sup> Martínez-Zarzoso *et al.* (2009) identified such possible trade effects under FTA. For the details about interpreting static integration effects, see Table 1, p.53.

<sup>22</sup> Linnemann (1966) added to the equation even the product of two countries' populations.

<sup>23</sup> The estimated variables, except dummies and probabilities, are expressed in logarithms.

$$\begin{aligned}\beta_{1,od} &= \beta_{10,od} + u_{1,od}, \\ \beta_{2,od} &= \beta_{20,od} + u_{2,od},\end{aligned}\tag{7}$$

where:  $BTC_{t,od}$  – bilateral trade costs,  $D_{p,t,od}$  – set of  $p$  dummy variables for the pair of countries (*ExEMU*, *ImEMU*, *BothEMU*, *Border*, *Sea*, *OfficialLanguage* and *LanguageProficiency*),  $P_{s,f,od}$  – set of probability variables that two trading partners are able to communicate in the certain  $f$  language (*LanguageCommunication*),  $I_o$ ,  $I_d$  – time-invariant individual (country) effects,  $I_t$  – time effect,  $u_{od}$  – trading pairs (level-2) random effects.

Equation (5) captures the variation in the time series, characterizes bilateral trade flows by the time varying variables with relatively larger variability: the national incomes' product and common internetization rate. The  $od$  subscript indicates that the intercept and slope coefficients are allowed to vary across the trading pairs found at level 2. The fixed-part of the model describes the given trading pair and the random-part at level-2 describes how 504 trading pairs vary around the average. The  $\beta_{00}$  coefficient measures the overall intercept across all trading pairs,  $\beta_{0,od}$  is interpreted as the intercept of the dependent variable for the pair  $od$  (which is different from the flows from country  $d$  to country  $o$ ;  $o$  describes origin and  $d$  – destination of the trade flow) and  $\beta_{10,od}$ ,  $\beta_{20,od}$  measure the overall slopes across all trading pairs. The fixed-part of 2-level model (6) captures the fixed effects that the rest of variables have on the variability of average levels of trade across trading country pairs ( $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_p, \alpha_s, \gamma_1, \gamma_2, \gamma_3$ ).

Since the bilateral export flows are nested not only within trading pairs, but also within particular areas such as northern and southern Europe, or inside and outside EMU area, the study considers the third level in the model, namely the place diversion: intra-EMU trade, the inter-EMU trade and outside-EMU trade.

Combining the first, second and third level models yields to the following model:

$$\begin{aligned}EX_{t,od,k} &= \beta_{00} + \beta_{10,od}GNIproduct_{t,od} + \beta_{20,od}Internetization_{t,od} + \alpha_1BTC_{t,od} \\ &+ \alpha_2 Research_{t,od} + \alpha_3 EnergyUse_{t,od} + \alpha_4 HighTechExport_{t,od} \\ &+ \alpha_p D_{p,t,od} + \alpha_s P_{s,f,od} + \gamma_1 I_o + \gamma_2 I_d + \gamma_3 I_t \\ &+ u_{0,od,k} + u_{1,od,k}GNIproduct_{t,od} + u_{2,od,k}Internetization_{t,od} \\ &+ v_{0,k} + v_{1,k}GNIproduct_{t,od} + v_{2,k}Internetization_{t,od} + \varepsilon_{t,od,k},\end{aligned}\tag{8}$$

where:  $t$  – level 1 (year),  $od$  – level 2 (state = trading pair),  $k$  – level 3 (place),  $v_{0k}$  – the random effect at the place level (EMU diversion), an allowed-to-vary departure from the grand mean,  $u_{0,od,k}$  – the random effect at the trading pairs level, a departure from the place effect,  $\varepsilon_{t,od,k}$  – the random effect at the year level, a departure from the trading pair effect within a place.

Table 2 presents the estimation results for all the specified models. The 3-level and 2-level models with random coefficients for GNI product and common internetization rate, according to the equations (8) and (5) were estimated in turn. Then, the simple Pooled Model (level-1 model), which incorrectly assumes that individuals are independent and leads to underestimation of standard errors and incorrect inferences, was computed. The deviance values, together with results of LR test comparing both models (see Table 3)<sup>24</sup>, showed that the random-intercept models are preferred.

The slope for each trading pair equals the fixed-effect slope for the whole sample, plus the random-effects slope for that pair. The calculated total effects (predicted random effects are in the sum) provide information on how the relationship between bilateral export flows and incomes' product and between bilateral export flows and common internetization rate vary across trading pairs. The coefficients of random slopes in the 3-level model (EMU diversion) are significant only for incomes' product. However, implementing the 2-level model gives significant estimates for common internetization rate, too. Hence, the final 3-level model contains random slopes for intercept and national incomes' product at every single level and a random slope for common internetization rate at the first and second levels. The estimates of the mixed models are computed by means of the maximum likelihood method, with the use of Stata 13 software<sup>25</sup>.

Based on the average estimated random effects of Model 2, the equation (8) for the export from Germany to Poland would be:

$$\begin{aligned} E\hat{X}_{DEU-POL} = & (-17.12 - 1.33 - 5.94) + (0.61 + 0.02 + 0.09)GNIproduct + (0.15 + 0.13)Internetization \\ & - 0.13BTC + 0.08Re searchers + 0.10HighTechEx + 0.13EnergyUse \\ & + 0.08ExEMU + 0.98Border + 0.72Sea + 1.92EnglishCommunication \\ & + 3.48FrenchCommunication + 3.76exporter + 0.38importer \end{aligned} \quad (9)$$

and alternatively, from Poland to Germany as follows:

<sup>24</sup> The  $H_0$  of the likelihood ratio (LR) test assumes that there is no significant difference between the two models.

<sup>25</sup> Stata's commands allow the estimation of the random effects with BLUP method – Best Linear Unbiased Prediction that show the amount of the variation for both the intercept and the estimated coefficients of  $\ln GNIproduct$  and  $\ln Internetization$ . According to Robinson (1991), 'BLUP estimates of the realized values of the random variables  $u$  are *linear* in the sense that they are linear functions of the data,  $y$ ; *unbiased* in the sense that the average value of the estimate is equal to the average value of the quantity being estimated; *best* in the sense that they have minimum mean squared error within the class of linear unbiased estimators; and *predictors* to distinguish them from estimators of fixed effects'. The estimators of random effects are commonly called as 'predictors' while estimators of fixed effects are called 'estimators', however, as a matter of fact both are estimators.

Table 2.

Estimation results of 2-level and 3-level gravity models

InEXPORT VARIABLES	3-level models		2-level models					1-level model
	Model 1	Model 2	Random-intercept Model	Model 3	Model 4	Model 5	Model 6	Pooled Model
InGNProduct	0.651*** (0.0302)	0.610*** (0.0441)	0.945*** (0.0229)	0.651*** (0.0297)	0.654*** (0.0302)	0.654*** (0.0302)	0.655*** (0.0302)	0.862*** (0.0355)
InBTC	-0.138*** (0.00409)	-0.138*** (0.00409)	-0.202*** (0.00467)	-0.138*** (0.00409)	-0.138*** (0.00409)	-0.138*** (0.00410)	-0.138*** (0.00410)	-0.554*** (0.00454)
InResearchers	0.0773* (0.0416)	0.0761* (0.0414)	0.00125 (0.0350)	0.0752* (0.0417)	0.0750* (0.0417)	0.0703* (0.0416)	0.0710* (0.0416)	0.176*** (0.0317)
InInternetization	0.165*** (0.0292)	0.152*** (0.0291)	0.183*** (0.0189)	0.166*** (0.0289)	0.167*** (0.0290)	0.166*** (0.0291)	0.165*** (0.0291)	0.202*** (0.0272)
InHighTechEx	0.103*** (0.0154)	0.103*** (0.0153)	0.218*** (0.0145)	0.104*** (0.0154)	0.104*** (0.0154)	0.104*** (0.0154)	0.104*** (0.0154)	0.0905*** (0.0236)
InEnergyUse	0.147** (0.0708)	0.133* (0.0706)	-0.0219 (0.0664)	0.150** (0.0716)	0.149** (0.0720)	0.135* (0.0701)	0.131* (0.0706)	0.0187 (0.0188)
InEMU	0.204*** (0.0241)	0.198*** (0.0241)	0.182*** (0.0245)	0.198*** (0.0239)	0.197*** (0.0240)	0.196*** (0.0240)	0.195*** (0.0240)	0.188*** (0.0336)
ExEMU	0.0888*** (0.0216)	0.0836*** (0.0217)	0.0402* (0.0222)	0.0835*** (0.0215)	0.0830*** (0.0216)	0.0821*** (0.0216)	0.0812*** (0.0215)	-0.103*** (0.0314)
BothEMU	0.185*** (0.0270)	0.177*** (0.0270)	0.194*** (0.0282)	0.186*** (0.0265)	0.185*** (0.0270)	0.184*** (0.0270)	0.184*** (0.0267)	0.208*** (0.0449)
Border	0.962*** (0.0763)	0.980*** (0.0762)	0.978*** (0.0772)	1.080*** (0.0762)	1.073*** (0.0774)	0.949*** (0.0752)	1.019*** (0.0742)	0.218*** (0.0194)
Sea	0.706*** (0.151)	0.719*** (0.151)	0.480*** (0.137)	0.613*** (0.158)	0.618*** (0.158)	0.694*** (0.153)	0.614*** (0.154)	0.195*** (0.0304)



InEXPORT VARIABLES	3-level models			2-level models				1-level model	
	Model 1	Model 2	Random-intercept Model	Model 3	Model 4	Model 5	Model 6	Pooled Model	
OfficialLanguage	0.315* (0.189)	0.303 (0.189)	0.243 (0.191)	0.314* (0.170)	0.274 (0.186)	0.390** (0.189)	0.345** (0.164)	-0.00703 (0.0419)	
English	-0.00676 (0.0152)	-0.0106 (0.0151)	-0.0558*** (0.0123)		-0.00540 (0.0152)	-0.00688 (0.0151)	-0.00646 (0.0151)	-0.0182 (0.0173)	
German	0.00519 (0.0485)	0.0120 (0.0481)	-0.0475 (0.0411)		0.00127 (0.0469)	0.00398 (0.0484)		-0.174*** (0.0375)	
French	-2.261*** (0.833)	-2.255*** (0.834)	-2.395*** (0.820)		0.138 (0.253)	-2.930*** (0.808)		-0.305* (0.182)	
EnglishCommunication	1.906*** (0.337)	1.922*** (0.337)	1.584*** (0.352)			1.808*** (0.334)	1.705*** (0.341)	0.527*** (0.0791)	
GermanCommunication	-0.336 (0.291)	-0.388 (0.290)	-0.0737 (0.294)			-0.254 (0.288)		0.0331 (0.0874)	
FrenchCommunication	3.551*** (1.214)	3.478*** (1.217)	4.015*** (1.186)			4.641*** (1.177)		0.621*** (0.264)	
Constant	-16.18*** (1.770)	-17.12*** (2.040)	-29.69*** (1.329)	-15.45*** (1.731)	-15.57*** (1.770)	-16.23*** (1.763)	-16.05*** (1.765)	-20.53*** (1.718)	
time-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
country-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# groups	3 / 504	3 / 504	504	504	504	504	504	504	504
# observations	6,533	6,533	6533	6533	6533	6533	6533	6533	6533
deviance	-528.9	-540.96	1185.64	-478.32	-478.74	-518.98	-502.54	5591.76	
sd(GNIproduct)	0.105 (0.013)	0.102 (0.012)		0.1035 (0.012)	0.1029 (0.012)	0.102 (0.012)	0.102 (0.012)	0.102 (0.012)	

Table 2.

InEXPORT VARIABLES	3-level models		2-level models				1-level model	
	Model 1	Model 2	Random- intercept Model	Model 3	Model 4	Model 5	Model 6	Pooled Model
sd(Internetization)	0.187 (0.19)	0.219 (0.18)		0.212 (0.019)	0.212 (0.018)	0.214 (0.018)	0.217 (0.018)	
sd(cons)	6.306 (0.544)	5.878 (0.508)	0.473 (0.016)	6.072 (0.504)	6.046 (0.509)	5.958 (0.501)	5.982 (0.503)	
corr(GNI,Internetization)	0.644 (0.266)	0.295 (0.193)		0.426 (0.215)	0.429 (0.215)	0.430 (0.211)	0.402 (0.204)	
corr(GNI,cons)	-0.997 (0.005)	-0.991 (0.003)		-0.992 (0.004)	-0.993 (0.004)	-0.994 (0.004)	-0.992 (0.004)	
corr(Internetization,cons)	-0.666 (0.210)	-0.403 (0.166)		-0.510 (0.178)	-0.513 (0.177)	-0.513 (0.173)	-0.494 (0.169)	
sd(residual)	0.178 (0.002)	0.178 (0.002)	0.227 (0.002)	0.178 (0.002)	0.178 (0.002)	0.178 (0.002)	0.178 (0.002)	0.371 (0.003)
sd(GNIproduct)		0.054 (0.022)						
sd(_cons)	0.151 (0.068)	1.118 (0.621)						

Source: author's calculations using Stata software. Parentheses enclose standard errors; \*\*\*:  $p < 0.01$ , \*\*:  $p < 0.05$ , \*  $p < 0.1$ .

$$\begin{aligned}
E\hat{X}_{POL-DEU} = & (-17.12 - 1.33 - 2.09) + (0.61 + 0.02 + 0.02)GNIproduct + (0.15 + 0.09)Internetization \\
& - 0.13BTC + 0.08Re searchers + 0.10HighTechEx + 0.13ln EnergyUse \\
& + 0.20Im EMU + 0.98Border + 0.72Sea + 1.92EnglishCommuncation \\
& + 3.48FrenchCommunication + 0.56exp orter + 3.76importer.
\end{aligned} \tag{10}$$

As both countries compose one trading pair, the fixed part and the 3-level random coefficients are common, the only differences between them are at level 2, where each pair has its own additional slope for the intercept,  $\ln GNIproduct$  and  $\ln Internetization$ , own country fixed effects and trade division effect's value of dummy. As expected, the respective estimates for export flows from Germany (the country is Europe's export leader) to Poland are relatively larger than for the oppositely-directed flows.

Two residual intraclass correlations for the estimated 3-level nested model (10) can be calculated. First, the level-3 intraclass correlation at the place level, that is the correlation between annual export flows in the same trade-place but for different trading pairs that takes the following form:

$$\text{intra-place correlation} = \frac{\sigma_{v0}^2}{\sigma_{v0}^2 + \sigma_{u0}^2 + \sigma_e^2}. \tag{11}$$

The second, level-2 intraclass correlation at the pair-within-place level (between annual export flows of the same pair in the same place) is:

$$\text{intra-pairs correlation} = \frac{\sigma_{v0}^2 + \sigma_{u0}^2}{\sigma_{v0}^2 + \sigma_{u0}^2 + \sigma_e^2}. \tag{12}$$

The error terms and random intercept are assumed to be normally distributed with mean 0 and variances  $\sigma_{v0}^2$ ,  $\sigma_{u0}^2$  and  $\sigma_e^2$ , and to be mutually independent.

The calculated residual intraclass correlations of Model 6 show that the annual export flows are only slightly correlated within the same place of trade (0.035), but they are extremely highly correlated within the same trading pair and place of trade, namely pair and place random effects compose approximately 99% of the total residual variance.

According to LR test results, there is a statistically significant difference also between the random-intercept model and all the relevant versions of random-coefficients models – the extended models (Models 1-6) provide a better fit. Model 5, which contains all the potential variables, is the most preferred among all of the 2-level models, however, it must be noted that not every effect is statistically significant, namely the effects of English and German proficiency and the probability of communications in German as well. An unexpected sign has French's coefficient, as it describes negative relation between trade flows and the common French proficiency.

However, the effects of communication in French are strongly positive and are more meaningful for the trade costs than the negative impact of the proficiency variable, which is actually created only by Belgium, France and Luxemburg, because only in the pairs of those countries the French language is official or spoken by more than 20% of the population. According to those results, the French speaking countries trade relatively less with each other than with other countries of the EU. The communication in English and French raises the trade exchange, which confirms the increasing importance of the quality of human capital in the international trade.

Table 3.

Results of the likelihood-ratio test

LR tests	Chi-square	P-value	Assumption	Preferred model
Model 5 / Model 2	21.98	0.0000	Model 5 nested in Model 2	Model 2
Model 5 / Model 1	9.92	0.0016	Model 5 nested in Model 1	Model 1
Random-intercept Model / Model 5	1704.62	0.0000	Random-intercept Model nested in Model 5	Model 5
Pooled Model / Random-intercept Model	4406.13	0.0000	Pooled Model nested in Random-intercept Model	Random-intercept Model

Source: author's calculations using Stata software.

The estimates of EMU dummies in the models indicate, that in the time period 1999–2011 there was significant trade creation in terms of imports with more pure effect in terms of exports ( $\phi_3 > \phi_1 > \phi_2 > 0$ ). The intra-EMU trade is relatively larger, but the extra-EMU trade is growing as well and there is no trade diversion effect ( $\phi_2, \phi_2' > 0$ ) – however, members' import effects are much larger than member's export effects, which does not seem to encourage non-EMU-members to join the EMU, since they still benefit from the export to EMU area. As a matter of fact, the positive net export is more desired, especially by developing economies, since it creates the national income.

#### 4. CONCLUSION

This study uses two hierarchical linear models to examine the effects of both traditional and globalization-connected variables on bilateral trade flows between EU countries. All the considered variables, apart from proficiency in English and German as well as the probability of communication in German, exert a significant influence on the average level of trade. The estimation results are consistent with the theory of gravity model, where trade flows decrease with the rise of bilateral trade costs, which

are a synthetic variable in the estimated models, based on travel time between country centroids and importer's openness.

Additionally, the impact of two variables: national incomes' product and common internetization rate, together with the intercept effect, vary across trading country pairs due to the heterogeneity in the sample. Both income and internetization have a positive impact on trade across trading pairs but the income also influences bilateral trade depending on the place of trade. The economic potential of the countries enhances the exchange more by the extra- and inter- than by intra-EMU trade. The distribution of random slopes of common internetization between the different places of trade is similar to the distribution of GNI slope, but is much closer to the estimated fixed effect of this variable. The hierarchical structure of the estimated models allows the formulation of the conclusion that the policy of increasing the national wealth and the quality of the network infrastructure leads to a relatively larger average increase of bilateral trade flows in the case of non-EMU-members than in the Eurozone. The intra-EMU trade is less dependent, however, overall larger since the common membership in EMU increases the trade flows. The estimation results are not completely accordant with the second hypothesis, which assumes the pure trade creation effect of the Eurozone. According to the model there is indeed the trade creation caused by EMU, however, in terms of the import. The positive signs of trade diversion-variables signify no trade diversion effects in the EU in the time period 1999–2011. The EMU members trade relatively more intensively not only with each other, but with non-EMU-members as well. Their economic conditions allow them for larger imports, which contributes to the trade creation effects of EMU.

All the coefficient estimates of the variables, that characterize the progress of globalization, provide grounds for the first research hypothesis verification, confirming the positive and significant impact of globalization on the international exchange.

Moreover, the estimates of language variables show that a common official language can increase the bilateral trade flows, however, not in the case of French speaking countries. According to the model, the ability of communicating in English and French increases the bilateral trade flows, when the impact of communication in German remains insignificant. Since the impact of French proficiency is significantly negative in the model, only the English language seems to be the true *lingua franca* within the area of the EU, which, in fact is the verification of the third hypothesis.

Further research could extend the model by including a larger research sample of countries, essentially other big trade partners of the European Union. Among other problems that remain open for consideration, the following should be mentioned: the use of hierarchical models by empirical analysis of other globalization processes, as migration or foreign direct investment flows, and the use of dynamic model, especially by the larger time period of research.

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#### HIERARCHICZNE MODELE LINIOWE BILATERALNYCH PRZEPLÝWÓW HANDLOWYCH MIĘDZY PAŃSTWAMI UNII EUROPEJSKIEJ

##### Streszczenie

Empiryczne modele grawitacji międzynarodowych przepływów handlowych estymowane są często metodą FE, której wadą jest iż, mimo zastosowania stałych efektów, zróżnicowanych dla wszystkich jednostek w badanej próbie, zakłada jednakowe oceny parametrów zmiennych użytych w modelu. W niniejszej pracy problem heterogeniczności rozwiązany jest za pomocą modeli mieszanych, pozwalających na zróżnicowane efekty pomiędzy parami nie tylko dla stałej, ale dodatkowo dla produktu dochodów narodowych oraz wspólnego poziomu internetyzacji. Estymowane dwa oraz trzy poziomowe modele dla danych z okresu 1999–2011 wykazują istotny wpływ tradycyjnych zmiennych modelu grawitacji oraz czynników związanych z postępem globalizacji.

**Słowa kluczowe:** model grawitacji, model mieszany, bilateralne koszty handlu, biegłość językowa, globalizacja, internetyzacja

#### MULTILEVEL MODELLING OF BILATERAL TRADE FLOWS BETWEEN EUROPEAN UNION COUNTRIES

##### Abstract

Empirical research of international trade with the use of gravity model is often estimated with the FE estimator. Indeed, this method is appropriate in the face of heterogeneity, that is typical of pairs of countries, which influence the effect of the determinants of bilateral trade. However, the disadvantage of the FE approach is that it assumes all the slopes of the variables of interest are common across all trading pairs in the sample. The use of mixed effects model in this study allows the coefficients of national incomes' product and the common internetization rate of trading countries to vary across the pairs. In order to capture unspecified heterogeneity by allowing the intercept and slopes to have a stochastic component in their variation, the 2-level and 3-level hierarchical linear models are estimated based on the data from the

period 1999–2011. The results indicate that not only typical gravity model factors, but also globalization factors as internetization rate, researchers rate, share of high-technology products' export, energy use, foreign languages proficiency and monetary union influence the bilateral trade between EU-members.

**Keywords:** gravity model, mixed-effects model, bilateral trade costs, language proficiency, globalization, internetization

