REVIEW OF THE USAGE OF GRAVITY MODELLING APPROACH IN ESTIMATING BILATERAL TRADE FLOWS

Selena Begović
Ekonomski fakultet Sarajevo

This paper aims to present the main developments of gravity model and its usage in estimating bilateral trade flows' determinants. Furthermore, it emphasises the importance of determining the adequate model specification in order to get the unbiased and reliable estimation results. In this respect, the importance of accounting for the trade barriers and trade history between trading partners, as well as different methods for estimating these effects, are elaborated in the paper. As there is no consensus on which variables should be included in the model or how the model should be estimated it is important to take into account the best practice in the recent studies, presented in this paper, in order to get more precise results.

Key words: *conventional gravity model, generalised gravity model, bilateral trade flows, fixed effects, history effect*

JEL classification: *F10, C20*

1. INTRODUCTION

There are many factors that can enhance or inhibit bilateral trade flows. The gravity model, which has been successfully used for over 40 years for estimation of bilateral trade determinants, includes economic mass (national income) of countries of interest and the distance between them as major bilateral trade determinants (the conventional model). In the recent studies economists use gravity model extended by other variables assumed to be important determinants of international trade flows. However, there is no consensus on which variables, other than those from the conventional model, to include in the model as determinants of bilateral trade flows. Determinants usually used in the recent studies are: regional trade agreements (Yamarik and Ghosh, 2005, Rose 2000, 2005), variability of exchange rate (Pugh et al, 1999; Clark et al, 2004), membership in institutions which promote trade (Rose, 2005, Engelbrecht and Pearce, 2007) and the effects of border on trade (Anderson and Wincoop, 2003).

Furthermore, there is a debate whether to use lagged dependent variable in these model in order to capture so called 'history effect' which can have a great impact on bilateral trade and its determinants. Usage of the fixed effects which are stated to be capturing 'history effect' (Anderson and Smith, 2007), as well as 'multilateral resistance' indices (Feenstra, 2002), and other unobserved (heterogeneity) effects (Cheng and Wall, 2005), has become also widely discussed in the recent literature on gravity modelling.

In this paper the main reasons for usage of gravity model in estimation of bilateral trade determinants will be presented. Furthermore, developments of both conventional and generalised gravity model will be elaborated. Finally, current practice in a usage of gravity model in international trade literature will be presented and importance of determination of appropriate model specification will be emphasised, as usage of inappropriate model specification can lead to biased and incorrect results.

2. JUSTIFICATION OF USAGE OF GRAVITY MODEL IN ESTIMATING BILATERAL TRADE FLOWS

The gravity model has been widely and successfully used for the estimation of different types of flows such as migration, tourism, commuting and other types of flows. It has also become commonly used in analysing different effects on international trade for over 40 years. The inspiration for the first specification of this model comes from Newton's Low of Gravitation where an analogy between trade and gravitation is made – gravitation is positively correlated with masses of two objects and negatively correlated with distance between them. If we translate this to bilateral trade flows – trade between two countries is positively correlated with their economic masses (usually proxied by their GDPs) and negatively correlated with distance between them.

The gravity model has been characterized as "a very simple model that explains the size of international trade between countries with a remarkably consistent (and thus, for economics, unusual) history of success as an empirical tool" (Rose, 1999, p. 14). Eichengreen and Irwin (1998, p. 34) also note that "few aggregate economic relations are as robust" as gravity model. Even though it was criticised for not relying on theoretical foundations, the gravity model has become extremely popular in the empirical literature. Moreover, with the passage of time, economists created relevant theory ad hoc to support existing gravity model. Frankel (1997) emphasised four reasons for the success of usage of the gravity model in the international trade estimations. First, modern theories of trade based on differentiated products provide an improved theoretical foundation for the gravity equation. Second, the gravity model proved to be quite successful in estimating bilateral trade flows. Third, there has been an increased interest in empirically testing of the trade effects of regional trading arrangements. Fourth, there has been a new interest among economists in the subject of geography and trade.

For a long time, and especially in the recent studies, there has been a debate between uses of two types of gravity models. The first is the *conventional gravity model,* which was not based on the theory but its theory has rather been developed ad hoc; and another is the *generalised gravity model,* which was derived from theory and which aimed to (but not yet succeed to) replace the conventional model. After presentation of the developments of both types of models, the current state of practice will be presented as a guide for determination of the most correct specification.

3. DEVELOPMENTS OF CONVENTIONAL GRAVITY MODEL

The first specification of the gravity model, which dates back to 1962 when Tinbergen made an analogy of Newton's Gravitation Law with trade, is usually called the conventional (traditional) gravity model. According to the conventional model (*equation 1*), which is nested in the generalised gravity model (*equation 2*) which is subsequently developed, countries will trade more the higher the incomes they have and the closer they are (Poyhonen, 1963).

Conventional gravity model:

$$PX_{ij} = \beta_0 + \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 D_{ij} + \beta_4 A_{ij} + u_{ij} \quad (1)$$

Where:

- PX_{ij} is the value of the trade flow from country i to country j;
- β_0 is the constant term;
- GDP_i (GDP_j) is the value of nominal GDP in country i (j);
- D_{ij} captures the effect of distance between countries i and j (used as a proxy for transaction costs);
- A_{ij} is any other factor(s) either aiding or resisting trade between countries i and j;
- u_{ij} is a log-normally distributed error term with $E(\ln u_{ij}) = 0$.

The conventional gravity model did not have any theoretical foundation at the time it was introduced. However, soon after its introduction, it was realised that this model may be derived from a general equilibrium model of export supply and import demand (Linnemann, 1966, cited in Pugh et al., 1998). With introduction of the 'new trade theory'[1] in the late 1970s and early 1980s (e.g. Kru-

[1] New trade theory suggests that trade flows between countries of similar size are expected to exceed trade flows between countries of differing size (Pass et al., 2008).

gman 1979, 1980, Helpman 1981, cited in Baldwin and Taglioni, 2006) started a trend where the gravity model was transformed from having too few theoretical foundations to having too many (Baldwin and Talglioni, 2006). Furthermore, at one point in time theory on the gravity model has been developing faster than empirical capabilities as it was not possible to estimate some effects suggested by theory at the time when the relevant theory has been developing (like the effect of history, which will be discussed later).

The conventional gravity model has been used to estimate the impact of different determinants of bilateral trade (such as free trade agreements, exchange rate variability, currency union, common language or common border) depending on the interest of the particular study. While some economists were trying to improve the conventional model by augmenting it and corroborating from underlying theory others, like Eichengreen and Irwin (1998), were trying to make it work better.

In 1998 Eichengreen and Irwin emphasised the importance of shared history between countries in free trade areas, arguing that free trade agreements may be result of previous connections and relations between countries. In order to capture this effect they suggested inclusion of lagged dependent variable (LDV) in the gravity model. They estimated their gravity model with a lagged dependent variable, which appeared to be statistically significant and to lower the effect of free trade agreements (which may be spuriously overestimated when the lagged dependent variable is not included in the model[2]). However, as the lagged dependent variable is likely to be correlated with unobserved terms from the past, which are captured by the error term, the inclusion of the lagged dependent variable is likely to induce a problem of endogeneity. Another problem with the lagged dependent variable is its interpretation. It can indicate that past trade flows influence current trade flows, but it can also capture the effect of random factors to which the lagged dependent variable may be related. In order to solve these problems Eichengreen and Irwin (1998) suggested an instrumental variables strategy.

2 This suggests that history matters and that controlling for previous trade patterns may diminish the estimated impact of trade policies on trade flows.

Moreover, Eichengreen and Irwin underlined the importance of sunk costs on trade preferences – once established, trade flows between two countries (which require great sunk costs) are not likely to be disturbed by changes of some trade determinants in the short term. Furthermore, history can also affect trade through political, historical and economic circumstances from the past, such as wars, recessions, exchange rate shocks, affiliation, networks and other temporary or permanent changes that may have permanent effect on trade of observed countries (Anderson and Smith, 2007).

Although Eichengreen and Irwin found the evidence and offered explanation for hysteresis their suggestion was widely ignored in subsequent literature. However, if hysteresis is a real phenomenon characterising trade, many gravity models which did not take it into account, even though they seemed theoretically justified and empirically correct, suffer from missing-variable bias (Anderson and Smith, 2007). On the other hand, inclusion of the lagged dependent variable may cause the problems for empirical estimation emphasised by Eichengreen and Irwin. However, with the development of empirical methods (especially the introduction of dynamic panel estimation) which allowed accounting for endogeneity this issue came into prominence again.

Schaefer et al. (2008) emphasised the importance of determination of effects that generate bilateral trade before determination of model specification. They showed (by Monte Carlo simulations) that if trade is generated by a lagged dependent variable and is estimated by the Newtonian (traditional conventional) model or with free trade agreements (FTA) model (conventional model with FTA variable(s) included) false estimates will result. In 2007 Anderson and Smith suggested that history effect can be captured by fixed effects[3] so that omitting lagged trade does not induce bias results[4] as Eichengreen

[3] "Fixed effects, by soaking up the effect of all time-invariant variables and factors that affect trade at the level of particular partners, may also capture the unique historical features that affect trade" (Anderson and Smith, 2007, p. 282).

[4] "Once the theoretically preferred gravity model is employed, accounting for the past with lagged dependent variables generally does not add information that is not included in other variables, particularly fixed effects. But that is not to say that history does not matter. Rather, fixed effects appear to capture enough history so that omitting lagged trade does not introduce bias" (Anderson and Smith, 2007, p. 281).

and Irwin argued. They estimated static and dynamic panel and note that: “All coefficients are much smaller in the presence of the LDV. But, when adjusted for the long-term, the coefficients revert to virtually the same level as results of (static panel) equation” (Anderson and Smith, 2007, p. 286). However, Schaefer et al. (2008) argued that estimation by fixed effects when trade is generated by a lagged dependent variable, and other way round, is likely to result in false results on the estimated coefficients.

If country fixed effects exist but are incorrectly estimated with a LDV model, the influence of GDP, per-capita GDP, common colonizer, mutual-colony status, and distance are all exaggerated (false positive). These results certainly give reason for some caution about routinely including lagged dependent variables in gravity models; conversely, if trade is generated by a lagged dependent variable process, but modelled as trade-pair fixed effects with no LDV, coefficients are all statistically significant but also significantly different from the true parameter values. The errors in the GDP and per-capita GDP coefficients are striking (Schaefer et al., 2008, p. 11-12).

Since researchers cannot know in advance which influence is present in the data it is suggested to estimate and present the results from both (static and dynamic) regressions.

4. DEVELOPMENTS OF GENERALISED GRAVITY MODEL

The conventional gravity model did not predict inclusion of prices of trading goods arguing that prices are likely to be averaged away in the long run as they are likely to adjust continuously to equate supply and demand (Leamer and Stern, 1970, cited in Pugh et al, 1998). Conversely, Anderson (1979) argued that products are differentiated among countries rather than homogenous and that the conventional model is misspecified as it does not include price terms. Bergstrand (1985) supported the idea and emphasised four assumptions (perfect substitutability of goods internationally in production and consumption; perfect commodity arbitrage; zero tariffs; zero transport costs) on which the conventional gravity model is based arguing that those assumptions are not likely to hold in the real world. He derived a gravity model from the micro foundations (utility functions for representative consumers and production function for representative firms) and in his corresponding empirical specification, he used the price terms and exchange rate variables to capture so called price effects (later called 'border effects') as prices are not equalised across countries (if we relax the aforementioned assumptions), so the pattern of trade is more complex than suggested by the conventional model. This model is known as generalised gravity model.

Beside price terms Bergstrand (1985) also expanded the gravity model by adding variable for exchange rate between the currencies of the trading partners and dummy variables for preferential trading agreements, the variables which was afterwards usually included in gravity modelling of international trade (*equation 2*).

Bergstrand's generalised gravity model:

$$PX_{ij} = \beta_0 + \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 D_{ij} + \beta_4 A_{ij} + \beta_5 ER_{ij} + + \beta_6 EUV_i + \beta_7 IUV_j + \beta_8 P_i + \beta_9 P_j + \beta_{10} FTA_{ij} + u_{ij} \quad (2)$$

Where:

- ER_{ij} is the bilateral nominal exchange rate between the currencies of countries i and j;
- EUV_i (IUV_j) is the export (import) price or unit value index of country i (j);
- P_i (P_j) is the producer/wholesale price index of country i (j)
- FTA_{ij} is free trade agreement between countries i and j.

In 1987 Thursby and Thursby estimated a model similar to Bergstrand's but slightly modified by introduction of risk in international trade (proxied by exchange rate variability) and so called 'Linder effect' which captures the potential intra-industry trade relations between countries[5] (*equation 3*). They also emphasised the importance of hedging opportunities when the effect of exchange rate variability on trade is being measured but as those opportunities are not directly measurable they stated that they can be captured by exchange rate variability measures[6].

Thursby and Thursby's generalised gravity model:

$$PX_{ij} = \beta_0 + \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 D_{ij} + \beta_4 A_{ij} + \beta_5 ER_{ij} + \\ + \beta_6 EUV_i + \beta_7 IUV_j + \beta_8 P_{i} + \beta_9 P_j + \beta_{10} VAR_{ij} + \beta_{11} Z_{ij} + u_{ij} \quad (3)$$

Where:

- VAR_{ij} is the variability of the bilateral exchange rate between the currencies of countries i and j;
- Z_{ij} is the absolute difference in the per capita incomes of countries i and j (Linder effect).

Oguledo and MacPhee (1994) also included price terms in their gravity model and expanded it with the variables which measure effects of discriminatory trade agreements on bilateral relations between two countries; they included not just dummy variables for preferential trade agreements but also dummies for discriminatory trade agreements (such as a socialist dummy) and tariff averages (in order to estimate resistance to imports) (*equation 4*) which turned out to be significantly negative. They also indicate that prices may

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5 Linder effect points out that similarity in levels of per capita income between countries have positive effect on trade between them.

6 "While most studies of gravity model have abstracted from issues of foreign exchange risk we include HI (factor reflecting any hedging done by importers) and HE (factor reflecting any hedging done by exporters) in underlying demand and supply functions to allow us to test for effects of exchange risk on value of trade. Since direct measures of HI and HE do not exist for trade aggregated over goods, we follow other studies in using variability in the exchange rate as a proxy for both." (Thursby and Thursby, 1987, p. 490).

be disturbed by non-tariff barriers and do not always turn out to have a significant effect on international trade flows.

Oguledo and MacPhee's generalised gravity model

$$\log M_{ij} = \log\gamma' + \alpha_1 \log Y_i + \alpha_2 \log N_i + \alpha_3 \log P_i + \beta_1 \log Y_j + \beta_2 \log N_j + \\ + \beta_3 \log P_j + \varepsilon_1 \log \widehat{TC}_{ij} + \varepsilon_2 \log t_j + \varepsilon_3 \log d_{ij} + u_{ij} \qquad (4)$$

Where,

- M_{ij} is the foreign price value of imports from country i to country j;
- Y_i (Y_j) is the national income in country i(j);
- N_i (N_j) is the population size in country i(j);
- P_i (P_j) is the general price level in country i(j);
- $\widehat{TC}_{ij}$ is a distance between countries i and j (transportation costs);
- t_j is advolorem tariff posed by country j on imported goods from i;
- d_{ij} is a preferential dummy which captures any effects of preferential treatment that a tariff coefficient might not pick up.

Consequently, for a period of time in studies which have used the gravity model approach it has been common to average data over short time series in order to average away any short-term disequilibrium with the intention of avoiding inclusion of price terms in the model. However, in 2003 Anderson and Wincoop published the paper: "Gravity with Gravitas: a solution to the border puzzle", which was a kind of 'comeback' of the generalised gravity model. They emphasised the importance of multilateral resistance (also called 'border effect'), which is one of the key implications of the theoretical gravity equation but was usually ignored in empirical gravity literature causing biased estimates. According to the theory, trade between two regions depends on the bilateral barrier between them relative to average trade barriers that both regions face with all their trading partners (Anderson and Wincoop, 2003). Therefore, the border effect should be included when estimating bilateral trade relations. In order to measure this effect and to get unbiased estimates they included price terms arguing that previous studies which estimated the border effect by using the conventional model (usually just by inclusion of variable 'remoteness'[7]) suffer from omitted variables bias and prevents economists from conducting comparative static exercises.

As mentioned above, Bergstrand (1985), Thursby and Thursby (1987), Oguledo and MacPhee (1994) included price terms in their studies, but they used published aggregate price indices which were criticised for non-accurately reflecting the 'true' border effect. That is, "the myriad of costs (money, time and currency risk) involved in making transaction across the border are probably not reflected in aggregate price indexes" (Feenstra, 2002, p. 497). Anderson and Wincoop took into account those costs by using price indices which they called 'indexes of multilateral resistance'. Although these indices are unobserved, Anderson and Wincoop calculated them by using a set of nonlinear equations (the so called computational method). This method was criticised as well, as it requires custom programming to perform the constrained minimisation and for assuming symmetric bilateral trade costs (Baier and Bergstrand, 2009).

Since multilateral indices are unobserved, rather than calculating them (through complex nonlinear equations), it is instead suggested to measure them as coefficients of source and destination region fixed effects which take into account the unobserved price indexes (Feenstra, 2002). Indeed, Anderson and Wincoop themselves — and nearly every gravity equation study since then — has employed this simpler technique of fixed effects for determining gravity-equation parameter estimates (Baier and Bergstrand, 2009). This approach which produces consistent estimates of the average border effect across countries is simple to implement and usually suggested in

[7] Remoteness variable measures how far an exporting country is from all other countries. "The intuition behind this variable is that bilateral distance expressed relative to the distance of each of the pairs from their other partners matters with there being a positive relationship between the remoteness of the exporting country and bilateral trade" (Yamarik and Ghosh, 2005, p. 23).

literature (Feenstra, 2002). However, Baldwin and Taglioni (2006) argued that measures of openness of the world to a nation's exports and measures of openness of a nation to imports from the world are not equal when there is a time dimension, which means that Anderson and Wincoop's model can be used in cross-section data but not in a panel data applications as it assumes equal transaction costs in bilateral trade relations. Therefore, Clark et al. (2004) recommended allowance of time variation in country fixed effects as it is more consistent with the theoretical concept of 'multilateral resistance' as such multilateral resistance indexes are likely to vary over time.

As evident from the presented studies there is no consensus about the specific specification of the gravity model, and which of the two presented types of gravity model should be used. Therefore, in the next section the variables and methods used in the recent studies will be presented.

5. VARIABLES INCLUDED AND METHODS USED IN THE CURRENT PRACTICE - IMPORTANCE OF DETERMINATION OF APPROPRIATE MODEL SPECIFICATION

Even though it is usually stated that the gravity model is empirically successful it is also argued that its success is based on goodness of fit (relatively high R^2) (Cheng and Wall, 2005). As some statistical results may be disordered as a result of incorrect specification of the model, which still seem to be statistically correct and strong and also consistent with theory, Schaefer et al. (2008) emphasised that findings from the gravity models should be taken "with a grain of salt". One of the potential reasons for such empirical success may be operation with a very large number of degrees of freedom[8] which makes it "relatively easy to obtain statistical verification whenever the model specification is elaborated in any way"

8 In gravity model bilateral relations are being observed and in the case of panel data of bilateral trade between n countries with observations for t time periods, there are $t*(n^2-n)$ available observations.

(Schaefer et al., 2008, p. 2), and which "has lulled researchers" into accepting biased results for a long period of time (Anderson and Smith, 2007, p. 281). However, with a passage of time economists have been realizing some failures and have tried to reach a model specification which does not suffer from these biases. Empirical developments have made this more likely to be the case.

Some researchers have been trying to improve the gravity model by including additional variables. For example, population variables became a part of the gravity model equation since Linneman in 1966 included this variable as an additional measure of the country size (Oguledo and MacPhee, 1994). Although it is still widely used in the studies we still do not know what this variable is exactly telling us. Oguledo and MacPhee (1994) noted that the effect of population size on trade is indeterminate – greater population size can induce trade as labour may specialise and create opportunities for trade in a wide variety of goods, but it can also inhibit trade as greater population may produce self-sufficiently to satisfy its own needs. Furthermore, this variable is not directly derived from any theoretical specifications and often proves to be statistically insignificant (Pugh et al., 1998). Therefore, it is sometimes suggested to use the 'Linder effect' which includes a population variable (as it is calculated as average absolute difference in per capita incomes between two countries) and which has an underlying rational – the closer the per capita incomes of two countries are there will be more (intra-industry) trade between them. Some researchers used similarity index and different measures of difference in relative factor endowments between countries to capture the substance of intra-industry trade[9], which is sole

9 "The similarity index (SIM_{ijt}) is expected to positively affect trade as more similar countries would likely engage in larger intra-industry trade flows. The variable for absolute difference in factor endowment (LRFAC) (measured as absolute difference in GDP per capita between two countries captures the difference in capital-labour ratios) should have a negative (positive) effect on trade volume if intra-industry (inter-industry) trade dominates, a paradigm that affords an opportunity to test the validity of the Linder (1961) hypothesis that the greater the disparity in factor endowments between trading partner countries, the smaller are expected trade flows between those countries" (Pass et al., 2008, p. 96);

$$\ln\left(SIM_{ijt}\right)=\ln\left[1-\left(\frac{GDP_{it}}{GDP_{it}+GDP_{jt}}\right)^2-\left(\frac{GDP_{jt}}{GDP_{it}+GDP_{jt}}\right)^2\right];\quad LRFAC_{ijt}=\left|\log\left(\frac{GDP_{it}}{POP_{it}}\right)-\log\left(\frac{GDP_{jt}}{POP_{jt}}\right)\right|.$$

manifestation of trade that prevails under assumption of new trade theory (Adam et al., 2003; Baltagi et al., 2003; Pass et al., 2008). Baltagi et al. (2003) and Paas (2008) additionally included the sum of two countries' real GDPs as a measure of bilateral overall country size (which controls for the size effect).

In empirical studies it has also become common to include dummy variables to account for shared characteristics between countries that are likely to induce or inhibit trade between them, such as: dummy variable for common border, common language, and membership in free trade agreements and institutions that promote trade (Clark et al., 2004). Monetary variables, such as exchange rate variability, currency union, foreign currency reserves[10] are also usually added in the gravity model (Kandogan, 2007). In most recent studies which use gravity model the spatial effects usually termed the 'multilateral resistance' effect (discussed in the previous section) are controlled for as well. Beside these, other variables have also been used in gravity literature, depending of the interest of particular study.

As there is no consensus on which variables should be included in gravity model and since misspecified model specification may result in bias estimates Yamarik and Ghosh (2005) conducted sensitivity analysis[11] and tested the robustness of 47 variables used in gravity model literature.

> Given the numerous gravity model specifications, each with a partial listing of variables that are significantly correlated with bilateral trade, researchers are uncertain as to the confidence they should place in the results of any one study. The choice of which variables to include and which to omit is of high importance since misspecification either lowers the precision of

[10] Matyas (1997) and Kandogan (2007) use foreign currency reserves of the importer as a measure of exchange rate stability.

[11] Yamarik and Ghosh (2005, p. 86) used a variant of Leamer's (1983, 1985) extreme-bounds analysis "which tracks the sign and significance level of the variable of interest to changes in the conditioning set of variables". Authors argued that by following a systematic approach to testing the fragility of coefficient estimates, extreme-bounds analysis allowed them to identify which independent variables are robustly linked to bilateral trade and which are not.

> the estimates, or worse, biases the estimates. Gravity empirics in the international trade literature would thus benefit greatly from robustness checking, which is the objective of this article. (Yamarik and Ghosh, 2005, p. 85)

The results of the sensitivity analysis indicate that only 19 variables are robustly linked to trade, although Yamarik and Ghosh (2005) called attention to potential problem with causality and multicollinearity between some of included variables. The robust variables in their analysis belong to the categories of the level of development, trade policy, linguistic and colonial ties, geographic factors, relative population density, common currency and membership in free trade agreements (although it turned out that memberships in only 5 from 12 tested trade agreements are robust).

Even though the gravity model was improved by inclusion of additional variables it was still criticised for resulting in biased estimates. During the time not just model specification was changing but also the method of estimation. Several authors (Breuss and Egger, 1999; Cheng and Wall, 2005) argued that the usage of cross-section methods results in biased estimates. Moving from the cross-sectional data to time-series panels "has allowed the use of a lagged dependent variable, country fixed effects for exporters and/or importers, log-first-differences of variables, and estimations of time-varying regression parameters" (Schaefer et al., 2008, p.3) (some of which were discussed in previous two sections) which have opened a new "set of dilemmas" in the gravity model approach but have allowed for accounting for potential problems with endogeneity, heterogeneity and omitted variable bias.

As it is usually not known where the heterogeneity comes from, in order to get unbiased estimates researchers recommended inclusion of fixed effects which capture unknown and/or unobserved factors which simultaneously explain trade volume between two countries (Matyas, 1997; Cheng and Wall, 2005, Paas, 2008). In the late 1990s, controlling for unobserved heterogeneity dominated the discourse as it pertained to identifying the correct specification and estimation techniques relevant for the gravity equation (Paas, 2008). Cheng and Wall (2005, p. 55) noted that "In the absence of any economic arguments for believing that the intercepts of the gravity equation are the same across trading pairs, we conclude that the FE [fixed effects] model is the more appropriate specification".

However, there has been little agreement about how to actually specify the fixed effects. For example, Mátyás (1997) included exporting and importing country fixed effects and time fixed effect (*equation 5*) while Cheng and Wall (2005) proposed inclusion of bilateral country-pairs and time dummies (*equation 6*). Baltagi et al. (2003) used a whole set of fixed effects: fixed exporter, importer and time effects (which they refer to as main effects) and interaction effects: country-pair time-invariant effect, exporter specific time-variant effects and importer specific time-variant effects (*equation 7*).

$$\ln EXP_{ijt} = \alpha_i + \beta_j + \gamma_t + \lambda_1 Y_i + \lambda_2 Y_j + \lambda_3 DIST_{ij} + \ldots + \varepsilon_{ijt} \qquad (5)$$

$$\ln EXP_{ijt} = \gamma_t + \alpha_{ij} + \lambda_1 Y_{it} + \lambda_2 Y_{jt} + \lambda_3 N_{it} + \lambda_4 N_{jt} + \varepsilon_{ijt} \qquad (6)$$

$$\ln EXP_{ijt} = \mathbf{x}'_{ijt}\delta + \alpha_i + \beta_j + \gamma_t + (\alpha\beta)_{ij} + (\alpha\gamma)_{it} + (\beta\gamma)_{jt} + \varepsilon_{ijt} \qquad (7)$$

Country fixed effect (α_i and β_j) control for time-invariant individual country characteristics. Country-pair fixed effects ($\alpha_{ij} = (\alpha\beta_{ij})$) allow for different preferences of countries towards different trading partners and they control for the impact of any time-invariant determinant specific for each trading pair such as bilateral distance, common language or common borders (Paas, 2008). Furthermore, by including time fixed effect (γ_t) we can adjust for different time effects common to all country pairs such as business-cycle effects or global shocks which affect all countries from the sample. Country time (home-time and host-time) interaction effects ($(\alpha\gamma)_{it}$ and $(\beta\gamma)_{jt}$) are country specific time-variant effects like the exporter/importer country's business cycle, its political, or institutional characteristics/

developments, and unobserved factor endowment variables (Baltagi et al., 2003).

From the review of theoretical and empirical studies it seems that all dilemmas about inclusion of different variables/effects which were present in the developments of gravity model resulted in inclusion of the fixed effects (which are believed to capture those different specific effects). For example, for the dilemma about the inclusion of the lagged dependent variable (discussed in section 3) one of the offered solutions, proposed by Anderson and Smith (2007), is inclusion of country specific and time fixed effects, which they argued to capture enough history so that omitting lagged trade (when fixed effects are included) does not induce bias estimates. Another dilemma related to the multilateral resistance effect (discussed in section 4), raised by Anderson and Wincoop (2003), was proposed to be solved by inclusion of the fixed effects rather than by using complicated calculations (since these effects are unobservable) which appeared to give consistent estimates of the average border effect (Feenstra, 2002). Matyas (1997) and Kandogan (2007) proposed measuring of trade bloc effects through the fixed effects (the former through country-specific fixed effects and the latter through country-pair-time varying interaction effects) rather than through dummy variables for blocs. However, the inclusion of these fixed effects will ignore potentially useful information contained in other variables which will probably drop out from the equation (in order to prevent perfect multicollinearity) once fixed effects are accounted for (Yamarik and Ghosh, 2005). For example, inclusion of country-pair fixed effects will most likely result in exclusion of time-invariant variables like distance, common border, common language - variables whose effect is useful to observe. Furthermore, country time-varying interaction effects prescribe omitting variables that vary over time but that remain fixed in the presence of different trading partner countries. The GDP of the exporting or importing country is one such variable (Paas, 2008) and should therefore drop out from the equation when those interaction terms are accounted for although it is one of the main variables of the gravity model.

6. CONCLUSION

In this paper the main developments of gravity model used for the assessment of bilateral trade flows are presented. The main determinants which should be controlled for in these types of estimations are emphasised and differed approaches in estimating these effects are elaborated. However, there is still no consensus about the specification or method which should be used when estimating bilateral trade flows and therefore these should be based on a combination of the best practice in the recent studies, which is presented in this paper, and researcher's interest.

On one side, even though it is recommended in the recent literature to use fixed effects to capture different effects on trade we have to emphasise that one should be careful with this strategy since the usage of fixed effects may prevent estimation and interpretation of some important effects on bilateral trade (such as GDP, common language, etc.), and we have to bear in mind that fixed effects are a "black box" and one cannot be sure that they contain what one think (and want) them to. There is also a potential problem of multicollinearty if lot of fixed terms are included as well as potential problem with biased estimates if dynamic relationships are present. On the other side, although those models (composed of fixed effects) are peculiar and do lack precision, if we are not interested particularly in some effects (for example GDP, common border, common language) on trade we can substitute them by fixed effect variables and observe their significance as a group (through the F-test) – in that context it may be econometrically and economically justified to sacrifice some variables which are not of particular interest for the more precise estimates of variables we are interested in. In conclusion, as suggested in the literature, the usage of fixed effects is justified when estimating bilateral trade flows by using gravity model, but researchers have to be careful with the extent of their use. Since there is still no agreement about the estimation strategy of hysteresis and since its importance in trade models is suggested in many recent studies we suggest estimation of both fixed effects static model as well as estimation of dynamic model. If lagged dependent variable turns out to be significant dynamic model should be preferred since we cannot be sure whether the 'history effect' is actually captured by fixed effects.

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PREGLED UPOTREBE GRAVITACIONOG MODELA PRI ESTIMACIJI BILATERALNIH TRGOVINSKIH ODNOSA

U članku je predstavljen tok razvoja gravitacionog modela i njegove upotrebe u estimaciji determinanti bilateralnih trgovinskih odnosa. Dalje, istaknut je značaj ispravnog specificiranja modela u cilju dobijanja pouzdanih rezultata estimacije. U tom kontekstu, značaj kontrolisanja za efekat trgovinskih barijera i trgovinske historije između trgovinskih partnera i različite metode estimiranja ovih efekata su obrazloženi u ovom članku. Obzirom da ne postoji koncenzus o tome koje varijable bi trebale biti uključene u model, niti o načinu estimacije, prilikom određivanja modela važno je uzeti u obzir najbolju praksu skorijih studija, koja je prezentovana u članku, u cilju dobijanja što preciznijih rezultata.

Ključne riječi: *konvecionalni gravitacioni model, generalizovani gravitacioni model, bilateralni trgovinski odnosi, fiksni efekti, historijski efekat*

JEL klasifikacija: *F10, C20*