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EVALUATION OF LATVIA' S AGRI-FOOD TRADE USING THE GRAVITY MODEL

The research aim in this article is to construct the gravity model for Latvian agri-food trade to be used further for the evaluation of the determinants of trade flows as well as for the prediction of future trade flows of the country. The results of the study confirm that the key determinant of trade flows in this case is the GDP per capita in Latvia and in a partner country. The negative impact of long distance on trade development is also confirmed. Imports from the EU are highly significant for Latvia, while EU exports are moderately significant. Exports to CIS and Russia in particular are also moderately significant. Forecast with the application of the gravity model shows the positive development trend for Latvia's net exports of agri-food.

Keywords: *Latvia; agri-food trade; gravity model; trade flows; exports and imports.*

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ВИКОРИСТАННЯ ГРАВІТАЦІЙНОЇ МОДЕЛІ ДЛЯ ОЦІНЮВАННЯ АГРОПРОДОВОЛЬЧОЇ ТОРГІВЛІ ЛАТВІЇ

У статті представлено гравітаційну модель латвійської торгівлі сільськогосподарськими товарами. Дану модель використано для виявлення та оцінювання ключових факторів впливу на торговельні потоки, а також для визначення майбутніх торговельних потоків країни. Результати дослідження демонструють, що ключовим фактором впливу на зовнішню торгівлю Латвії є ВВП на душу населення самої Латвії та країни-партнера. Негативний вплив на розвиток торгівлі має відстань між країнами-партнерами. Імпорт в Латвію з країн ЄС можна характеризувати як життєво важливий для країни, а експорт – як суттєво важливий. Експорт до країн СНД та зокрема до Росії також можна назвати суттєво важливим для Латвії. Прогноз розвитку торгівлі з використанням гравітаційної моделі продемонстрував позитивний тренд розвитку латвійського валового експорту сільськогосподарської продукції.

Ключові слова: *Латвія; сільськогосподарська торгівля; гравітаційна модель; торговельні потоки; експорт та імпорт.*

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ИСПОЛЬЗОВАНИЕ ГРАВИТАЦИОННОЙ МОДЕЛИ ДЛЯ ОЦЕНКИ АГРОПРОДОВОЛЬСТВЕННОЙ ТОРГОВЛИ ЛАТВИИ

В статье представлена гравитационная модель для латвийской торговли сельскохозяйственными товарами. Данная модель использована для выявления и оценки ключевых факторов влияния на торговые потоки, а также для определения будущих торговых потоков страны. Результаты исследования показывают, что ключевой фактор влияния внешней торговли Латвии – это ВВП на душу населения самой Латвии и страны-партнёра. Негативное влияние на развитие торговли имеет расстояние между странами-партнёрами. Импорт в Латвию из стран ЕС жизненно важен для страны, а экпорт – существенно важен. Экспорт в страны СНГ и в частности в Россию также можно охарактеризовать как существенно важные для страны. Прогноз развития торговли с применением гравитационной модели продемонстрировал позитивный тренд развития латвийского валового экспорта сельскохозяйственной продукции.

Ключевые слова: *Латвия; сельскохозяйственная торговля; гравитационная модель; торговые потоки; экспорт и импорт.*

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Introduction. A consistent trade liberalization process during the last two decades has increased Latvia's economic integration within the global economy. In the period of globalization and expansion of multinational market forces, bilateral trade flows of agricultural commodities and processed foods (further in the text – agri-food) have consistently grown. The balance of Latvian agri-food trade traditionally in long term was negative (Melece, 2011). The dependency on imports is rather high, even in the product groups with potentially sufficient domestic supply (Ibid.). On the other hand, the capability of domestic producers to compete globally has opened new markets for exporters. Gravity models have been extensively used in the analysis of bilateral trade flows (Feenstra et al., 2001; Baxter and Kouparitsas, 2006; Marquez-Ramos et al., 2012;) due to their empirical success in determining trade potential of a country (Babecka-Kucharcukova et al., 2010; Kepaptsoglou et al., 2010; Shepherd, 2012). Although, gravity models have used previous analyzing Baltic States (including Latvia) trade, these studies are out of date (Byers et al., 2000; Laaser & Schrader, 2002) and mainly historically oriented.

The aim of the present study is to elaborate a gravity model of Latvian agri-food trade, selecting the appropriate estimator for the model to be used further in the evaluation of determinants of trade flows as well as in the prediction of future trade flows. Since its almost simultaneous introduction by J. Tinbergen (1962), P. Pyhonen (1963) and K. Pulliainen (1963), the gravity equation has been extensively used in approximation of the sizes of trade flows between any two countries. Similarly to the Newton's theory of gravitation, it is assumed that trade between two countries is directly proportional to the sizes of their respective economies (Rault et al., 2008), and inversely proportional to the distance between their economic centers (Demirkan et al., 2009). J.E. Anderson (1979) proved the suitability of gravity equation irrespective of specific product markets. Usually GDP per capita is selected as the proper measure of the country's economic strength and trade potential (Baldwin & Taglioni, 2011). This variable along with the partner countries' GDP per capita is expected to be positively related to trade as stated by H. Kalbasi (2001). These assumptions are based on the historical trade data, when countries irrespective of their size tend to have larger trade flows with economically stronger trade partners. Distance have the opposite influence on trade flows as it is more convenient and less expensive to trade with the closest countries. An increase in distance between countries is expected to increase transportation costs, thus reducing trade. According to H. Kristjansdottir (2005) this variable is expected to be negative. After the initially proposed exogenous variables, such as population, GDP, GDP per capita, the gravity model has been extended by the introduction of country-specific dummy variables. These variables cover geographic issues like common border, access to sea transport, absence of land borders, historical issues like colonial past, wars, alliances, economy issues like trade blocks, customs unions, preferential trade agreements, trade barriers, trade resistance, openness to trade and socio-demographic issues like religion and language.

Materials and methods. Generally, the gravity equation has the following log-linear form for the exports data panel:

$$\ln(X_i) = A + b\ln(GDPL) + c\ln(GDP_i) + d\ln(DST_i) + \sum_{j=1}^{n} \alpha_j D_{ji} + \varepsilon_i, \quad (1)$$

where X_i – exports from "base" country to country i; A – multiple regression intercept; b – regression coefficient for logarithm of "base" country GDP per capita; $GDPL$ – GDP per capita in "base" country; c – regression coefficient for logarithm of GDP per capita in country i; GDP_i – GDP per capita in country i; d – regression coefficient for logarithm of distance between "base" country and country i; DST_i – distance between "base" country and country i; α_j – regression coefficients for dummy variables, j = 1, 2, ..., n; D_{ji} – dummy variables specific for country i, j = 1, 2, ..., n; ε_i – regression error term for country i.

Similarly, by denominating Mi for imports to "base" country from country i, the gravity equation for imports data panel can be obtained. The empirical results of previous research suggest that gravity equation can be applied in about 80% of cases. In a gravity model for bilateral trade, panel data are annual trade flow values for a specified country with its trade partner countries, observed for several years. Usually data forms a short panel, meaning a large cross section of countries observed for a few time periods rather than a long panel such as a small cross section of countries observed for prolonged time periods. In a balanced data panel, the number of time periods is the same for all countries. Most research on bilateral trade flows is restricted to balanced panels, and ex-ante determined number of countries is included in panel data. Thus, the research results reflect only a part of trade flows. This approach is convenient because of elimination of zero trade values.

The unbalanced panels include entire trade data with the possible absence of trade for a particular country in a number of years. The first major advantage of panel data is increased precision of estimation as a number of observations increases by combining several years of data for each country in a pooled model. For valid statistical inference a control for likely correlation of regression model errors over time for a given country is necessary. The most commonly used calculation of standard errors in a pooled OLS regression usually overstates precision gains. Thus, standard errors can be underestimated and t-statistics can be inflated. As stated by P. Egger and M. Pfaffermayr (2000), pooled model also does not allow for heterogeneity of countries. It does not estimate country specific effects and assumes that all countries are homogenous. It is a restricted model. The second advantage of panel data is the possibility of consistent estimation of the fixed effects model, which allows for unobserved country heterogeneity that may be correlated with regressors. Such unobserved heterogeneity leads to omitted variable bias that in practice may be difficult to be corrected by instrumental variables. P. Egger (2000) recommends the selection of a fixed effects model when estimating trade flows with balanced panels. The third model is random effects model, when any unobserved individual heterogeneity is treated as being distributed independently of regressors. Compared to fixed effects model, the advantage of random effects model is the consistent estimation of all parameters. The main problem of the pooled model is that it does not fit for countries' heterogeneity. A random effects model can be more appropriate when estimating the flows of trade between a randomly sample drawn of trading partners from a large population. A fixed effects model would be a better model when estimating trade flows between ex ante predetermined selection of countries.

The 3 most common panel data models can be estimated by 5 common estimators – pooled OLS, between, within (fixed effects), first differences and random effects estimators. To determine the model for panel data, H.M. Park (2010) proposes the following sequence of statistical tests: F-test (Wald test) for the fixed effect model and Breusch-Pagan Lagrange Multiplier (LM) test. Hausman test is needed if both fixed and random effects are found. The F-test (Wald test) tests the null hypothesis that a set of coefficients of dummy variables in a fixed effects model are simultaneously equal to zero. If the null hypothesis can not be rejected, it means that removing variables from the model will not substantially harm the fit of this model. The Breush-Pagan test (Lagrange multiplier test) tests a random effects model that helps to decide between a random effects regression and a simple OLS regression. The null hypothesis in the Breusch-Pagan test is that variance across entities is zero. This makes no significant difference across units (i.e. no panel effect). If both fixed effects and random effects are not found, data are poolable and model can be estimated by pooled OLS estimator. If there are fixed effects and no random effects, within (fixed effects) an estimator should be used. If there are random effects and no fixed effects, random effects estimator should be used. If both fixed effects and random effects are found, Hausman test is performed and within (fixed effects) or random effects an estimator should be used upon the results of the test.

Results and discussion. In many countries, researchers (Hatab et al., 2010; Paas, 2000) use balanced data panels with specified and limited list of partner countries. The advantage of such panels is the lack of zero values, as trade flows with major partners are present every year. The annual number of exporting countries to Latvia varies from 93 to 103 over the time period from 2002 to 2012. As for the imports, the variance is even more pronounced, and the annual number of importing countries from Latvia varies from 61 to 134 over the time period from 2002 to 2012. Therefore, the unbalanced data panels are used for both exports and imports, with all countries included. The data of Latvian foreign trade were retrieved from the UN Comtrade database, based upon the 6-digit HS nomenclature codes; the data on the GDP – from the OECD Statistical extracts database, the distances between the countries – from the CEPII database. The data panels comprise 1128 observations for exports, and 1065 observations for imports for the years 2002–2012. With both data panels, trade flows were regressed on independent basic variables – Latvian GDP per capita, partner countries' GDP per capita, distance between Latvia and partner country, and dummy variables – the EU member country, free trade agreements, common border, landlocked country, island country, former colony and former colonizer.

The gravity equation for Latvian exports data panel has the following log-linear form:

$$\ln(X_i) = A + b\ln(GDPL) + c\ln(GDP_i) + d\ln(DST_i) + \sum_{j=1}^{7}\alpha_j D_{ji} + \varepsilon_i, \qquad (2)$$

where X_i – exports from Latvia to country i; A – multiple regression intercept; b – regression coefficient for logarithm of Latvian GDP per capita; $GDPL$ – Latvian GDP per capita ($G1$); c – regression coefficient for logarithm of GDP per capita in country i; GDP_i – GDP per capita in country i (G_{2i}); d – regression coefficient for logarithm of distance between Latvia and country i; DST_i – distance between Latvia and country i (D_i); α_1 – regression coefficient for EU membership dummy variable; D_{1i} – EU membership dummy variable (E_i); α_2 – regression coefficient for free trade agreement dummy variable; D_{2i} – EU free trade agreement dummy variable (F_i); α_3 – regression coefficient for landlocked country dummy variable; D_{3i} – landlocked country dummy variable (D_i); α_4 – regression coefficient for island country dummy variable; D_{4i} – island country dummy variable (I_i); α_5 – regression coefficient for common border dummy variable; D_{5i} – common border dummy variable (B_i); α_6 – regression coefficient for colony dummy variable; D_{6i} – colony dummy variable (Ci); α_7 – regression coefficient for colonizer dummy variable; D_{7i} – colonizer dummy variable (Ri); ε_i – regression error term for country i.

The gravity equation for Latvian imports data panel takes the following log-linear form:

$$\ln(M_i) = A + b\ln(GDPL) + c\ln(GDP_i) + d\ln(DST_i) + \sum_{j=1}^{7}\alpha_j D_{ji} + \varepsilon_i. \qquad (3)$$

3 regression methods were used – pooled (simple OLS) regression, fixed effects, and random effects. The results of the regressions for exports data panel are provided in Table 1.

Table 1. **Gravity model estimation results for exports data panel**

Variable	Pooled regression	Fixed Effects	Random Effects
EU membership	1.803 (7.09)***	0.405 (1.55)	0.655 (2.63)***
Free Trade Agreements	-0.061 (-0.27)	0.083 (0.24)	0.020 (0.07)
Landlocked	-0.781 (-3.56)***	-	-0.784 (-1.47)
Island	-1.395 (-6.88)***	-	-1.464 (-3.22)***
Common Border	0.442 (0.83)	-	0.425 (0.28)
Colonized (CIS)	3.000 (9.35)***	-	2.992 (3.51)***
Colonizer (Russia)	5.372 (6.08)***	-	5.184 (2.00)**
Distance	-0.677 (-5.73)***	-	-1.007 (-3.92)***
Partner's GDP Per Capita	0.573 (9.50)***	0.671 (2.73)***	0.518 (4.40)***
Latvia's GDP Per Capita	0.342 (1.80)*	1.132 (5.03)***	1.125 (7.22)***
Constant	9.613 (5.12)***	-3.793 (-2.76)***	5.486 (2.24)**
Observations	1128	1128	1128
R-squared	0.45	0.10	0.43
Adjusted R-squared	0.45		
Goodness-of-fit test	92.39***	52.72***	
F-test		19.32***	
Breusch-Pagan (LM) test			995.89***
Hausman test		-	

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. All the other variables are statistically insignificant; t-statistics are in parenthesis.
Source: the authors' calculations based on the data from the UN Comtrade database.

For the exports data panel, the p-value associated with a chi-squared value generated by F-test is less than the generally used criterion of 0.05. Thus, the null hypothesis can be rejected, and the coefficients are not simultaneously equal to zero. The results of the test support the rejection of the pooled model and acceptance of the fixed effects model. The p-value of Breusch-Pagan test (Lagrange multiplier test) suggests the rejection of the null hypothesis that variances across entities have zero values. This means that the random effects model should be preferred to pooled model. However, the Hausman test for the exports data panel could not be performed due to the fact that model fitted on these data failed to meet the asymptotic assumptions of the test. Therefore, the estimated correlations between the error term and the regressors for both models were compared, indicating that random effects model should be preferred to the fixed effects model.

By substituting the regression coefficients in equation (2) with the values from random effects model, the following gravity equation for Latvian exports data panel is obtained:

$$\ln(X_i) = 5.49 + 1.13\ln(G1) + 0.52\ln(G2_i) - 1.01\ln(D_i) + 0.66E_i - 0.02F_i - 0.78L_i - 1.46I_i + 0.43B_i + 2.99C_i + 5.18R_i. \quad (4)$$

The equation was solved for all 1128 observations, and respective error values were obtained. The results of the regressions for imports data panel are provided in Table 2. For the imports data panel, the results of the F-test support the rejection of the pooled model and acceptance of the fixed effects model. The p-value of the Breusch-Pagan test (Lagrange multiplier test) suggests that the random effects model should be preferred to pooled model. The Hausman test for the imports data panel provide statistically significant p-value. Thus, the null hypothesis that the difference in coefficients is not systematic can be rejected. This means that the random effects model should be preferred to the fixed effects model.

Table 2. **Gravity model estimation results for imports data panel**

Variable	Pooled regression	Fixed Effects	Random Effects
EU membership	1.521 (5.86)***	0.460 (2.72)***	0.526 (3.16)***
Free Trade Agreements	-0.194 (-0.84)	-0.133 (-0.62)	-0.190 (-0.92)
Landlocked	-1.407 (-6.71)***	-	-0.971 (-1.56)
Island	-1.058 (-5.13)***	-	-1.305 (-2.19)**
Common Border	-0.060 (-0.11)	-	0.508 (0.27)
Colonized (CIS)	1.661 (4.98)***	-	1.280 (1.22)
Colonizer (Russia)	3.098 (3.55)***	-	2.725 (0.88)
Distance	-0.960 (-8.23)***	-	-1.260 (-4.14)***
Partner's GDP Per Capita	0.430 (7.32)***	0.538 (3.12)***	0.535 (4.42)***
Latvia's GDP Per Capita	0.220 (1.26)	0.412 (2.82)***	0.405 (3.46)***
Constant	15.476 (8.82)***	4.914 (5.82)***	14.764 (5.43)***
Observations	1065	1065	1065
R-squared	0.44	0.21	0.43
Adjusted R-squared	0.43		
Goodness-of-fit test	82.81***	39.63***	
F-test		47.23***	
Breusch-Pagan (LM) test			1948.14***
Hausman test		74.48***	

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. All other variables are statistically not significant; t-statistics are in parenthesis.
Source: the authors' calculations based on the data from the UN Comtrade database.

By substituting regression coefficients in equation (3) with the values from the random effects model, the following gravity equation for Latvian imports data panel is obtained:

$$\ln(M_i) = 14.76 + 0.41\ln(G1) + 0.54\ln(G2_i) - 1.26\ln(D_i) + 0.53E_i - 0.19F_i - 0.97L_i - 1.31I_i + 0.51B_i + 1.28C_i + 2.73R_i. \quad (5)$$

The equation was solved for all the observations, and the respective error values were obtained. The estimated results reveal that Latvian agri-food exports are positively and significantly affected by higher GDP per capita both in Latvia and in a partner country. Exports are significantly higher to the CIS countries. The significance of exports to the EU countries is significant, while significance of former colonizer (Russia) is somewhat lower. As anticipated, the negative impact on distance between trading partners is highly significant. Also trade with island countries has been significantly negative. Similarly to exports, Latvian agri-food imports are positively and significantly affected by higher GDP per capita both in Latvia and in partner country. Imports from the EU countries are highly significant. The negative impact on distance between trading partners on imports is highly significant. Also imports from island countries have been significantly negative. Determinants of Latvian agri-food trade with their statistical significance are provided in Table 3.

Table 3. **The determinants of Latvian agri-food trade and their statistical significance,** *authors' findings*

Variable	Exports	Imports
	Statistical significance and impact	
EU membership	high, positive	high, positive
Free Trade Agreements	–	–
Landlocked	–	–
Island	high, negative	moderate, negative
Common Border	–	–
Colonized (CIS)	high, positive	–
Colonized (Russia)	moderate, positive	–
Distance	high, positive	high, positive
Partner's GDP Per Capita	high, positive	high, positive
Latvia's GDP Per Capita	high, positive	high, positive

The prediction of future trade flows can be based only of the parts of the panels, which includes partner countries that had trade with Latvia in 2012, as the panels are unbalanced. Forecast GDP values are logarithmed and substituted into equations (2) and (3). The calculated values for every observation are summed with the respective error value. After that, the exponents from corrected values are calculated for every observation to obtain the proposed trade flows from their logarithms. Subsequently, the exponential values are summed across the all countries. Calculated predicted values of aggregate trade flows in 2013 along with the values in 2012 are provided in Table 4.

Table 4. **Predicted trade flow values in 2013,** *mln USD*

Trade flow	2012	2013*	Difference	Change, %
Exports	2,601	2,862	262	10
Imports	2,480	2,630	150	6
Net exports	121	232	111	92

* regression prediction.
Source: the authors' calculations based on the data from the UN Comtrade database.

The predicted growth of exports at 10% rate in 2013 exceeds the 6% predicted increase in imports. The positive value of trade balance (net exports) is expected to reach almost twofold increase.

Conclusions:

1. The annual number of exporting countries to Latvia varies from 93 to 103 over the time period from 2002 to 2012. As for the imports, the variance is even more pro-

nounced, and the annual number of importing countries from Latvia varies from 61 to 134 over the time period from 2002 to 2012. Latvian foreign trade in agri-food (agricultural commodities and processed foods) can be explained by gravity equation based on panels of trade flows expressed in value terms. With both data panels, trade flows were regressed on independent basic variables – Latvian GDP per capita, partner countries' GDP per capita, distance between Latvia and partner country, and dummy variables – the EU member country, free trade agreements, common border, landlocked country, island country, former colony and former colonizer. The random effects data panel model was appropriate for the panel data estimation by within (random effects) estimator.

2. The results of the regressions for imports data panel are the following: the F-test support the rejection of the pooled model and the acceptance of the fixed effects model; the p-value of the Breusch-Pagan test (Lagrange multiplier test) suggests that the random effects model should be preferred to pooled model, but the Hausman test for the imports data panel provide statistically significant p-value. Thus, the null hypothesis that the difference in coefficients is not systematic and can be rejected, and the random effects model should be preferred to the fixed effects model. The growth rate of exports predicted by the regression of exports on calculated time-invariant variables and forecast variables in 2013 would exceed the relative increase in imports.

3. A fixed effects model would be a better model when estimating trade flows between ex ante predetermined selection of countries. The results of this confirm that the main determinants of trade flows – GDP per capita in Latvia and a partner country have significant positive impact on trade.

4. As anticipated, the negative impact of the distance between trade partners is highly significant and the distance between Latvia and a partner country has significant negative impact on trade. Trade with island countries tends to be significantly or moderately lower. Imports from the EU countries are highly significant. Exports to the EU countries are moderately significant. Exports to the CIS countries are highly significant. Exports to Russia are moderately significant.

5. Usage of gravity model for prediction of trade balance in Latvia show that the forecast of the value of net exports of agri-food (agricultural commodities and processed foods) would be positive or, in other words, would increase in 2013.

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