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GRAVITY MODEL OF FOREIGN TRADE BETWEEN UKRAINE AND EU COUNTRIES

An analysis of the economic effects of Ukraine's trade with the EU is important for understanding the change in foreign trade relations of the parties after the signing of the Association Agreement with the EU. The article analyzes the changes of foreign trade of Ukraine with the EU countries after the signing of the Association Agreement using the gravity model of trade. The influence of various factors on the foreign trade flows of Ukraine's trade with the EU countries is determined, the relations and the nature of trade in goods with Ukraine with the EU member states are analyzed. The influence of the availability of resources and mutual relations of trading partners on the foreign trade relations of Ukraine with the EU countries has been determined. The conclusions on the development of trade potential after the Association Agreement with the EU have been formulated. The conclusions about the possibility and reliability of using the gravity model for forecasting the development of foreign trade relations, the intensification of trade in the context of regional trade union based on the performed regression analysis. The experience of modeling foreign trade relations on the basis of gravity model is generalized. The dependence of the size of trading partners on the volume of mutual trade of Ukraine with the EU and the dependence of the distance between economies on the intensity of trade relations have been proved.

Keywords: European economic integration, gravity model of trade, international trade, foreign trade effects.

Introduction. Ukraine has certainly taken the first step towards active participation in current international processes. Despite the fact that it is in the center of Europe, next to the progressive states that are actively transforming their economies, Ukraine is far behind and does not keep up with the processes taking place in neighboring countries. Ukraine has many opportunities to become more involved in the world economy. This transition to the world economy is facilitated by several reasons, such as: the advantage of geographical location, the presence of minerals, the importance of scientific and technical potential, the development of several industries and agriculture, the qualification of labor resources. EU integration processes in the EU and globalization of economic processes help to increase production rates in the country and increase consumption of commodity products, stimulate business development and increase the flow of goods and services in the EU direction, which is ensured by the regular flow of products from producers to consumers.

Creating a free trade area will open a new market for goods and services for Ukrainian producers. In general, the orientation vector for economic cooperation is of great importance for the economy of the state. It is important to calculate the impact of the implementation of the relevant arrangements on households, business and government. Therefore, the gravitational model of international trade can be used as a tool for analyzing how strong and close the trade relations of Ukraine with the EU countries are, and to determine priority directions for building mutually beneficial foreign trade relations and to analyze the nature of trade. The Gravity Trade Model allows us to make sound conclusions about the impact of factors that can enhance Ukraine's trade relations with EU countries.

The purpose of research. The aim of the study is to analyze the prospects for developing and deepening trade relations with EU countries in the context of integration processes, assessing the current state of trade of Ukraine with EU member countries using a gravity model, proving the dependence of the size of trading partners on the volume of mutual trade of Ukraine with the EU, as well as distances between economies on the intensity of trade relations.

Recent literature review. The gravitational model of trade was used in the scientific works of P. Poychonen and J. Tinbergen¹, where scientists in the models used such variables as national income,

¹ Tinbergen, J. (1962). *Shaping the world economy; suggestions for an international economic policy*. New York: The Twentieth Century Fund.

population, foreign trade turnover, distance between trading partners. J. Anderson¹ used a gravity model based on the Cobb-Douglas production model. E. Helpman and P. Krugman² developed a model of gravity trade based on the relationship between trade volume and market structure. Bergstrand³ used a gravity trading model based on the Heckscher-Olin model to study trade flows. E. Winkup⁴ developed a modern model of international trade using a multilateral resistance variable. Such researches as V. Moskovkin⁵, N. Chernov⁶, N. Kalyuzhnaya⁷ were engaged in the study of Ukraine-EU trade flows. In particular, Kalyuzhnaya N. described the foreign trade relations of Ukraine on the basis of the results of a comparative analysis of the classical specifications of the gravitational model of foreign trade. M. Novikova, N. Tkachuk⁸ described the nature of Ukraine's trade with the EU using Dummy variables.

Main research results. Exports of goods to the EU are steadily increasing, reaching a record high of \$ 20,158.5 million as of 2018. The United States, while in 2013 – a total of 16,758.6. In 2018 alone, exports to the EU increased by 15%. At the same time, the volume of exports to Asia and CIS countries in particular decreased during 2013-2018. Thus, the effect of Ukraine's trade reorientation towards EU markets is observed. The dynamics of the reorientation of exports of goods from Ukraine during 2013-2018 are shown in Table 1.

Table 1

Reorientation of exports of goods from Ukraine during 2013-2018, mln USD

	CIS Countries	US Countries (28)	Asia
2013	22,077.3	16,758.6	16,813.0
2014	14,882.3	17,002.9	15,350.9
2015	7,806.1	13,015.2	12,378.9
2016	6,031.5	13,496.3	11,796.3
2017	6,916.4	17,533.4	12,967.3
2018	6,363.1	20,158.5	13,486.0

Source: calculated by author according to⁹.

Thus, in 2018, the European Union is Ukraine's key trading partner.

In addition, data on the circulation of goods and services between Ukraine and EU countries in 2017-2018 empirically show that Ukraine has closer relations with individual countries than with others. This may be due to various factors: historical links, geographical proximity, developmental proximity, GDP level, and more. It is possible to investigate the relationship between the level of turnover and the distance between the EU and Ukraine by building a trend line. The trend line of goods turnover with goods from EU countries in 2018 is presented in Fig. 1.

¹ Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *The American economic review*, 69 (1), 106-116.

² Helpman, E., Krugman, P. R. (1985). *Market structure and foreign trade: Increasing returns, imperfect competition, and the international economy*. Cambridge: MIT press.

³ Bergstrand, J. H. (1989). The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *The review of economics and statistics*, 71 (1), 143-153.

⁴ Anderson, J. E., Wincoop, V. E. (2003). Gravity with gravitas: A solution to the border puzzle. *American economic review*, 93 (1), 170-192.

⁵ Moskovkin, V. M. Колесникова, Н. І., Рилач, Н. М. (2007). Гравітаційна модель для зовнішньої торгівлі України з країнами ЄС. *Бізнес Інформ*, 7, 26-32.

⁶ Чернов, Н. А. (2017). Внешняя торговля России: гравитационный подход. *Вестник университета*, 4, 79-84.

⁷ Калюжна, Н. Г. (2017). Підхід до визначення гравітаційних чинників впливу на зовнішньоторговельні відносини країн. *Проблеми економіки*, 1, 26-31.

⁸ Новикова, М. В., Ткачук, Н. Ю. (2011). Формування та тестування гравітаційної моделі зовнішньої торгівлі товарами України з країнами ЄС. *Проблеми підвищення ефективності інфраструктури*, 29 (29).

<<http://jrn1.nau.edu.ua/index.php/PPEI/article/view/282/271>> (2019, July, 03).

⁹ Офіційний сайт Державної служби статистики України (2019). *Головна сторінка* <<http://www.ukrstat.org.ua>> (2019, July, 03).

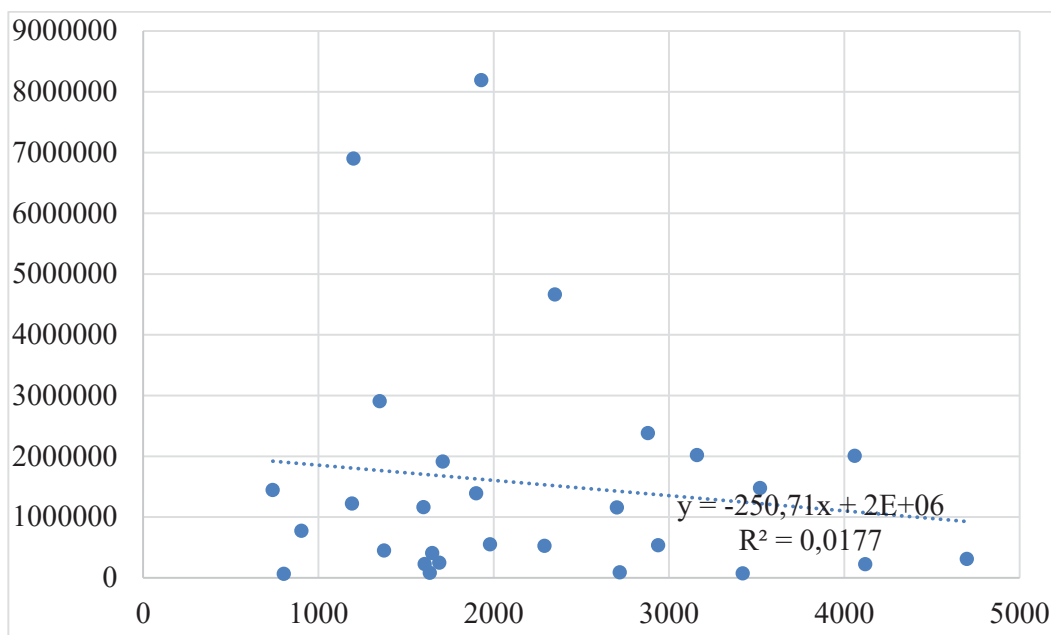


Fig. 1. Trend line of goods turnover with goods with EU countries in 2018, depending on the distance between Ukraine and EU, th. USD / km

Source: Created by author according to¹.

Thus, the linear equation of trade trend with EU countries in 2016 shows the level of certainty $R^2=0.0177$. In general, the reliability of the Least squares model is low. Therefore, to increase the reliability of the movement of goods from various factors, an additional criterion was introduced – the country's GDP. The dependence of trade on the distance between countries and GDP can be described using a gravity model.

Mathematically, the general gravity model can be described using equation 1.5. To analyze the nature and direction of Ukraine's EU trade in goods, to study the effects of integration, the use of a gravity model is possible. Mathematically, the general gravity model is described by the formula:

$$M_{ij} = k \frac{p_i \times p_j}{d_{ij}^2} \quad (1)$$

where M_{ij} – the metric of the interaction between the objects i and j ;

k – coefficient of conformity;

p – measure of the significance of the object (e.g., GDP of country i and j);

d_{ij} – distance between objects².

The equation of the model of the dependence of the commodity flow on GDP and the distance to Ukraine is:

$$T = \frac{A \times GDP^k}{d^t} \quad (2)$$

where A , k , t – model parameters (constants);

GDP – GDP of the country;

d – distance between countries³.

¹ Офіційний сайт Державної служби статистики України (2019). Головна сторінка <<http://www.ukrstat.org.ua>> (2019, July, 03).

² Ibid.

³ Щербата, З. Я. (2009). Застосування гравітаційної моделі при оцінці українсько-китайських економічних зв'язків. *Проблеми и перспективи развития сотрудничества между странами Юго-Восточной Европы в рамках Черноморского экономического сотрудничества и ГУАМ* : сб. науч. тр. ДонНУ, РФ НИСИ, 376-380.

According to the terminology, this regression model is "intrinsically linear", as it is reduced to a linear model by logarithmic transformation:

$$\ln(T) = \ln(A) + \ln(\text{GDP}) - \ln(T_p) \quad (3)$$

where T_p – estimated values of turnover;

T – actual turnover values;

A – model parameter (constant)¹.

At the same time, let us mark $g = \ln(T)$, $u_1 = \ln(\text{GDP})$, $u_2 = \ln(d)$, $b_0 = \ln(A)$, $b_1 = k$, $b_2 = -m$, then, the equation takes the form of linear regression:

$$G = b_0 + b_1 h_1 + b_2 h_2 \quad (4)$$

To adapt the model for approximate estimation of parameters it is possible to use the classical method of least squares:

$$S(b_0, b_1, b_2) = \sum (b_0 + b_1 h_{1i} + b_2 h_{2i} - g_i)^2 \quad (5)$$

In this case, the system of normal equations will look like:

$$\begin{cases} nb_0 + b_1 \sum h_{1i} + b_2 \sum h_{2i} = \sum g_i & (6) \\ b_0 \sum h_{1i} + b_1 \sum h_{1i}^2 + b_2 \sum h_{1i} h_{2i} = \sum g_i h_{1i} & (7) \\ b_0 \sum h_{2i} + b_1 \sum h_{1i} h_{2i} + b_2 \sum h_{2i}^2 = \sum g_i h_{2i} & (8) \end{cases}$$

The calculations of the regression model of the impact of Ukraine's trade flows with the EU are presented in Table 2.

Solution of the linear equation system 1.7. results in the following values for the coefficients: $b_0 = 5.84$; $b_1 = 0.814$; $b_2 = -1.22$.

Thus, passing from the coefficients to the parameters of the nonlinear regression model of equation 1.6., the following coefficients were obtained: $A = 339.3$; $k = 0.814$; $t = 1.22$.

Thus, the equation of gravity model of Ukraine's trade with the EU is as follows:

$$T = \frac{339.3 \times \text{ВВП}^{0.814}}{d^{1.22}}$$

The “Significance F” of the model indicates that there is a stable dependence of the turnover function (dependent variable) on independent factors (distance between countries, GDP of trade countries).

To evaluate the reliability of the model, the standard error of the model is calculated by the coefficient of determination:

$$\sigma = \sqrt{\frac{\sum (T_p - T)^2}{(n-3)}} \quad (9)$$

where T_p – estimated values of turnover;

T – actual turnover values;

n – the number of data points;

T – average turnover²

¹ Щербата, З. Я. (2009). Застосування гравітаційної моделі при оцінці українсько-китайських економічних зв'язків. *Проблеми и перспективы развития сотрудничества между странами Юго-Восточной Европы в рамках Черноморского экономического сотрудничества и ГУАМ*: сб. науч. тр. ДонНУ, РФ НИСИ, 376-380.

² Воскобойников, Ю.С. (2005). *Економетрика в Excel: Парний і множинний регресійний аналіз*. Воронеж: ИММиФ, 1.

Table 2

**Regression model of the impact of Ukraine's trade flows
with the EU based on 2018 data**

Country	T	GDP	d	ln(T)	ln GDP	ln(d)	ln(T _p)	T _{пор}	(T-T _{пор}) ²	(T-T _{cep}) ²
Austria	1161	459401	1600	7.1	13.0	7.4	7.5	1721.3	313857.4	150525.6
Belgium	1157	536055	2703	7.1	13.2	7.9	6.9	1029.9	16246.2	153420.8
Bulgaria	773	63651	904	6.7	11.1	6.8	6.5	690.3	6893.1	601815.5
United Kingdom	1476	2808899	3520	7.3	14.8	8.2	8.0	2876.4	1960044.9	5285.6
Greece	550	218057	1980	6.3	12.3	7.6	6.6	723.5	29976.5	997386.3
Denmark	526	354683	2290	6.3	12.8	7.7	6.8	900.5	140564.7	1047437.2
Estonia	248	29527	1690	5.5	10.3	7.4	5.1	172.2	5723.8	1693120.4
Ireland	221	366448	4120	5.4	12.8	8.3	6.1	451.9	53171.1	1762833.5
Spain	2007	1437047	4060	7.6	14.2	8.3	7.2	1400.2	367731.5	209392.5
Italy	4662	2086911	2350	8.4	14.6	7.8	8.2	3695.6	933435.2	9689114.9
Cyprus	63	23963	803	4.1	10.1	6.7	5.9	359.9	88049.6	2207845.3
Latvia	447	34286	1375	6.1	10.4	7.2	5.5	250.1	38599.0	1215484.6
Lithuania	1222	52468	1192	7.1	10.9	7.1	6.0	420.9	641442.8	107060.5
Luxembourg	90	68993	2720	4.5	11.1	7.9	5.3	192.4	10551.4	2129713.8
Malta	72	14270	3421	4.3	9.6	8.1	3.7	40.3	1025.0	2180721.7
The Netherlands	2380	909887	2880	7.8	13.7	8.0	7.3	1466.8	834017.3	690511.3
Germany	8192	402914	1930	9.0	12.9	7.6	7.1	1230.7	48455329.5	44124829.7
Poland	6899	549478	1201	8.8	13.2	7.1	7.9	2825.4	16595697.3	28623762.7
Portugal	309	237962	4700	5.7	12.4	8.5	5.6	270.8	1433.1	1538653.9
Romania	1444	239440	740	7.3	12.4	6.6	7.9	2592.2	1318826.3	11087.7
Slovakia	1390	106940	1901	7.2	11.6	7.6	6.1	425.6	929758.2	25359.3
Slovenia	224	54969	1607	5.4	10.9	7.4	5.7	303.8	6390.0	1756250.2
Hungary	2906	156393	1350	8.0	12.0	7.2	6.8	880.4	4104409.4	1842083.6
Finland	407	276553	1650	6.0	12.5	7.4	7.0	1096.6	475748.2	1304669.9
France	2018	2794696	3160	7.6	14.8	8.1	8.1	3267.2	1559999.6	220117.3
Croatia	81	59971	1636	4.4	11.0	7.4	5.8	319.0	56447.0	2153815.1
Czech Republic	1913	244540	1710	7.6	12.4	7.4	6.9	949.7	927511.2	132328.8
Sweden	536	554659	2939	6.3	13.2	8.0	6.9	956.2	176831.9	1026944.3

Source: authors' calculations based on ^{1,2,3,4,5,6,7,8}

¹ Офіційний сайт Державної служби статистики України (2019). *Головна сторінка* <<http://www.ukrstat.org.ua>> (2019, July, 03).

² Statistisches Bundesamt (Destatis) (2019). *Homepage* <<https://www.destatis.de/EN/Homepage.html>> (2019, July, 03).

³ Central Statistics Office Ireland (2019). *Homepage* <<http://www.cso.ie/en/index.html>> (2019, July, 03).

⁴ Główny Urząd Statystyczny Poland (2019). *Homepage* <<http://stat.gov.pl/en/>> (2019, July, 03).

⁵ Centrālā statistikas pārvalde Latvija <<http://www.csb.gov.lv/en>> (2019, July, 03).

⁶ Statistikaamet Eesti (2019). *Homepage* <<http://www.stat.ee/en>> (2019, July, 03).

⁷ Hungarian Central Statistical Office (2019). *Homepage* <<https://www.ksh.hu/?lang=en>> (2019, July, 03).

⁸ Офіційний сайт Центру соціальних досліджень ім. Разумкова (2019). *Головна сторінка* <www.razumkov.org.ua> (2019, July, 03).

The reliability of the model is determined by the following formula:

$$R^2 = 1 - \frac{\sigma_u}{\sigma_t} \quad (10)$$

where σ_u – standard error of regression of actual values;

σ_t – error of regression of mean values¹

To estimate the reliability of the model, the standard error of the model is estimated by calculating the standard regression error and determining the coefficient of determination according to formula 10. Thus, the coefficient of determination is $R^2 = 0.61$, which indicates the importance of the coefficient and the reliability of the model.

Conclusions. In this paper, using the gravity model, we analyze the international trade of Ukraine with EU countries. The obtained parameter estimates repeat the previous results in this direction: the economic size of the trading partners has a positive effect on trade volumes, the distance adversely affects the intensity of trade relations, that is, neighboring countries can count on more active relations. The results of the study confirm the hypothesis that countries with comparable levels of economies will trade more actively with each other.

Summarizing the experience of modeling foreign trade relations on the basis of the gravitational model, we can conclude the reliability and reliability of calculations using variables such as gross domestic product of trading partners, the distance between capitals of countries. In the process of calculations, it was confirmed that the model is adequate and that the input data are statistically significant and can, therefore, be used to model foreign trade forecasting.

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¹ Ibid.

13. Statistisches Bundesamt (Destatis) (2019). *Homepage* <<https://www.destatis.de/EN/Homepage.html>> (2019, July, 03). [in English].
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