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MODELLING THE ECONOMIC SECURITY OF REGIONAL EXTERNAL TRADE FLOWS

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Abstract. *Subject of research:* assessment and management of economic security of regional foreign trade flows of regions of Ukraine. *Methodology:* during the research, statistical analysis and analytical analysis (in the study of the main aspects of the formation of foreign trade flows of the region) are used. Mathematical modelling in economics (when creating a model of the two-dimensional normal distribution of regional foreign trade streams) and methods of analysis for risk assessment, conditioned by the formalization of the uncertainty of the operation of regional foreign trade operations are also used. *The purpose of scientific research:* mathematical modelling in economics in the management of economic security of export-import flows of regions of Ukraine; analysis of the structure of regional foreign trade flows in Ukraine and their respective risks; creation of the field of economic security of foreign trade flows of the region. *The conclusion of the research:* the study of limits and quantitative analysis of the risk of regional foreign trade flows in some regions of Ukraine is reduced to the creation of the area of crossing the main splicing ellipses of two-dimensional normal laws of export-import flows of these regions. After that, it will be possible to make a comparative assessment of the competitiveness and economic security of the regions. *The purpose of the article* is to develop an economic-mathematical model of quantitative risk analysis and to find appropriate boundaries of foreign trade flows of the region, which allows setting the thresholds of regional export-import operations for optimal management of the process of foreign trade flows of the region. The foreign trade flows of Ivano-Frankivsk, Mykolaiv, and Kherson regions of Ukraine based on a two-dimensional normal distribution are modelled. Areas of threshold values of indicators of foreign trade flows of regions from the point of view of economic risk are defined, which, in contrast to existing one-dimensional approaches, takes into account elements of the interconnection of foreign trade flows of the region. The methodical conditions for constructing split ellipses of foreign trade flows of the region for comparative estimation of the risk of competitiveness and economic security of the regions are developed. This will make possible to conduct a systematic analysis of the region's economic development and to take measures both at the local level and at the state level in order to neutralize a number of threats to its economic security.

Key words: export-import flows, differential function, two-dimensional normal distribution law, ellipse scattering.

JEL Classification: R580, C120

1. Introduction

It is known that the economic security of foreign trade operations of the region is related to the volumes of exports and imports, domestic prices, changes in the rates of national currencies, interest rates, aggregate demand and GDP, employment levels, and generally affects the macroeconomic equilibrium. At the same time, taking into account the complexity of the process of export-import operations in the region, the issues of mathematical modelling in economics of the risk of foreign trade flows of the region are not sufficiently studied, which play a significant role in the problem of regional economic recovery and management of the socio-economic development of the region. Therefore, the problems of studying models and methods of mathematical modelling in economics of economic security of foreign trade flows of the region have become a priority. Thus, the modelling of economic risk in the system of predictive-analytical calculations and improving the methods of managing regional risks is an important scientific task.

The close relationship between the elements of the foreign trade sphere and the economy of the country, in general, determine the need for effective state policy aimed at optimizing all processes and eliminating disproportions between the levels of socio-economic development of the regions. Taking this into account,

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the issue of establishing a system of indicators for regional export-import operations and their thresholds is relevant.

2. Literature review

Expansion of exports plays a significant role in the development of foreign trade in Ukraine. I.G. Kurochkina (2015) believes that Ukrainian producers need effective functional tools to stimulate exports – an increase in its physical and cost volume.

According to the official website of the State Statistics Committee of Ukraine (2015, 2016, 2017), we emphasize that in 2016, the surplus of the foreign trade balance amounted to 337.3 million dollars. According to the data, the volume of exports of goods and services in Ukraine in 2016 amounted to 44.885 billion dollars, and import – 44.548 billion dollars. Compared to 2015, exports shrank by 4.1% and imports increased by 3.7%. The foreign trade balance surplus amounted to 337.3 million dollars. In 2015, the surplus was 3.828 billion dollars. In January-November 2016, the import of goods exceeded exports by 2.324 billion dollars. The data are given without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part of the area of the anti-terrorist operation.

According to the official website of the State Statistics Committee of Ukraine (2015, 2016, 2017), over 9 months of 2017 the export of goods amounted to $31327.2 million, imports – $35199.2 million. Compared to 9 months of 2016, exports grew by 21.1% (by $5,454.5 million), import – by 27.3% ($7555.9 million). The negative balance was 3872.0 million dollars (9 months of 2016 were also negative – 1770.6 million dollars). Foreign trade operations were conducted with partners from 219 countries of the world.

It should be noted that, in the face of falling domestic purchasing power, exports are one of the most important factors of economic growth.

L. Dedyaev (2014) formulates the strategic goal of forming the commodity structure of Ukraine's exports taking into account high-tech products. M. Kryvoruchko (2015) believes that the indicators of export and import flows of minerals in the regions of Ukraine are not correlated with each other.

T. Melnyk, K. Pugachevska (2015) investigated the import dependence and export slope of the industry of the regions of Ukraine, which determines the consequences of exceeding the volume of imports over domestic production.

V.V. Oskolsky (2014) determines the reason for the low efficiency of the Ukrainian export of the regions according to Finger-Kreinin index. V.G. Andriychuk V.G., Ivanov E.I. (2014) assesses the export-import flows of the regions after the signing of the Association Agreement with the EU when the conditions of foreign trade with European trading partners for Ukraine have improved.

Lall, S.V., Koo, J. and Chakravorty, S. (2003) claim (using India as an example) that regions with less specialization and more diversified exports tend to experience higher rates of economic growth.

Lapshin V. I., Kuznychenko V. M., Ovcharenko Yu. S. (2014) analysed indicators that characterize the state of export and import flows in the regions of Ukraine in 2014 compared to 2013.

Marianne Matthee and Wim Naudé (2008) estimated a cubic-spline density function for the Herfindahl-index measure of export diversity. They found out that export diversity declines as the distance from an export hub increases.

O. Bilorus and O. Havryliuk (2015) propose to intensify the search for internal reserves to increase the competitiveness of domestic products and diversify our country's export position in the global economic space. This will provide the increase of volumes of external trade.

3. Finding a differential function of a normally distributed two-dimensional random variable of export-import flows in the Ivano-Frankivsk region

We shall use the following legend: GRP – gross regional product; EX_R – total volume of export of the region; IM_R – total volume of export of the country. Export regional dependency ratio $L^R_{exs} = \frac{EX_R}{GRP}$. The coefficient of import regional dependence $L^R_{ims} = \frac{IM_R}{GRP}$. In general, the threshold values of the indicators are defined in the economic literature, as $L^R_{exs} > 0,5$ and $L^R_{ims} > 0,5$.

Figure 1 shows the value of coefficients L^R_{exs}, L^R_{ims} for those regions, for which the values of these coefficients belong to the interval (0,25;0,5) in 2016.

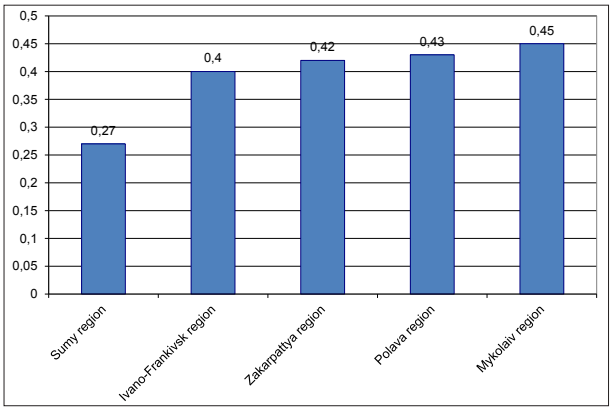


Fig. 1. The value of the coefficient of regional dependence from export $0,25 < L^R_{exs} < 0,5$ in 2016 by the regions of Ukraine

Source: Built by the authors on http://www.ukrstat.gov.ua

Figure 2 shows the value of coefficients L^R_{ims} for the regions, in which the values of these coefficients belong to the interval (0,25;0,5) in 2016.

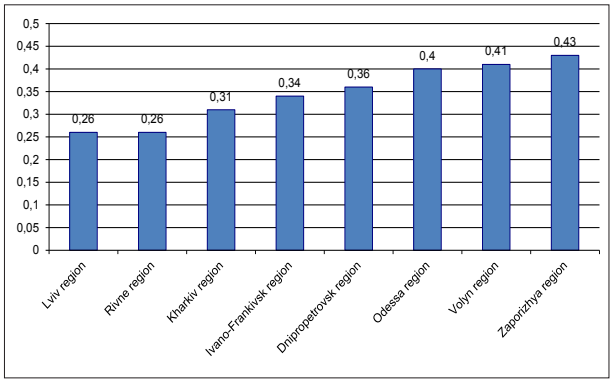


Fig. 2. The value of the coefficient of regional dependence from import $0,25 < L^R_{ims} < 0,5$ in 2016 by regions of Ukraine

Source: Built by the authors on http://www.ukrstat.gov.ua

We will select the Ivano-Frankivsk region, which is represented in Fig. 1 and Fig. 2. The export-import flows for this region are characterized as follows:

$$L^R_{exs} = 0.4, \quad L^R_{ims} = 0.34, \quad \frac{L^R_{exs}}{L^R_{ims}} = 1.17 . \qquad (1)$$

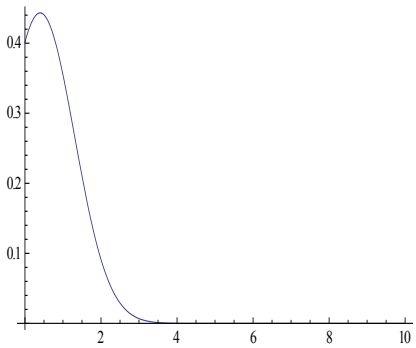
Although the export coverage coefficient is in the range of threshold values ($\frac{L^R_{exs}}{L^R_{ims}} > 1$), the coefficient of regional dependence from import and the coefficient of regional dependence from export do not reach their threshold values by 20% and 32%. For the analysis of export-import flows of Ivano-Frankivsk region, we consider the system of two independent compatible random variables X (export) and Y (import), which are statistically characterized by one-dimensional normal distribution laws – export regional flows (Fig. 3a):

$$N(0.4, 0.9), \quad M(X) = 0.4, \sigma_x = 0.9 ; \qquad (2)$$

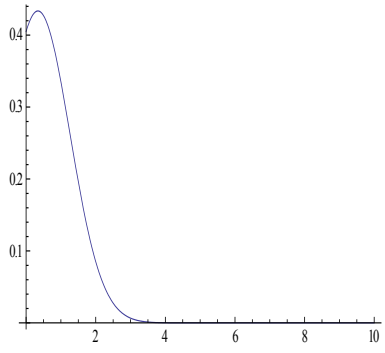
regional flows of import (Fig. 3b):

$$N(0.34, 0.92), \quad M(Y) = 0.34, \sigma_y = 0.92 . \qquad (3)$$

Their correlation coefficient $r_{xy} = 0$.



a)



b)

Fig. 3. One-dimensional normal distribution laws – export regional flows (a) and imported regional flows (b)

The differential function f (x, y) of a normally distributed two-dimensional random variable (X, Y) of the export-import flows of Ivano-Frankivsk region for the period of 2014–2016 is as follows:

$$f(x, y) = \frac{1}{3.352\pi} e^{-\frac{(x-0.4)^2}{1.62} \frac{(y-0.34)^2}{1.6924}} \qquad (4)$$

In space, the differential function (4) of the normal distribution (1) is represented by the surface (Fig. 4).

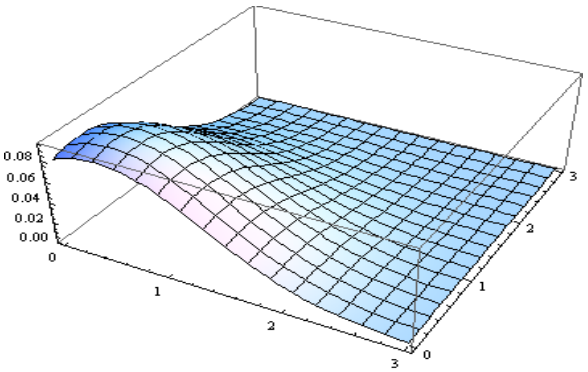


Fig. 4 The surface of the two-dimensional probability density of export-import operations in the Ivano-Frankivsk region

4. Determination of the area of permissible risk of export-import flows

We find the equation of the main scattering ellipse if the confidence probability of a random variable (X, Y) falling into the ellipse is 0.95. The equation of the principal ellipse of scattering has the following form:

$$\frac{(x-4)^2}{4} + (y-3)^2 = 5,9915 \qquad (5)$$

The plurality of points of the ellipse will be called the area of permissible risk of export-import flows in the Ivano-Frankivsk region.

We determine the area of permissible risk of export-import flows of the region in such form: $D = \{(x, y) \mid 0.4 < x < 0.6, 0.4 < y < 0.6\}$.

We find the probability of getting a normally distributed random variable (X, Y) into the area of permissible risk. We calculate:

$$P((x,y)\in D)=\left(\Phi\left(\frac{0.6-0.4}{0.9}\right)-\Phi\left(\frac{0.4-0.4}{0.9}\right)\right)\left(\Phi\left(\frac{0.6-0.34}{0.92}\right)-\right.$$
$$\left.-\Phi\left(\frac{0.4-0.34}{0.92}\right)\right)=(\Phi(0.2)-\Phi(0))(\Phi(0.28)-\Phi(0.06))=$$
$$=0,07926(0,11026-0,02392)=0,0068$$

Thus, for the random variables X and Y, the export-import flows of the Ivano-Frankivsk region, distributed according to one-dimensional normal laws, respectively, $N_x(0.4,0.9)$, $N_y(0.34,0.92)$, with a given confidence probability of 0.95, an area of admissible risk was found in the form of the principal split ellipse of the two-dimensional random variable (X, Y) of the export-import flows of the Ivano-Frankivsk region in the form of formula (5). The probability of a normally distributed random variable (X, Y) in the permissible risk region is found. As a result of the calculations, it is established that in 2016 the calculated indicators for the Ivano-Frankivsk region are not within the thresholds, therefore, the foreign trade activity of these regions needs to be adjusted.

5. Two-dimensional normal laws of distribution of export-import flows of the Mykolaiv and Kherson regions

We have a sample of the general population (X; Y) for the Mykolaiv and Kherson regions for 2014, 2015, 2016, and 2017.

Tables 1-2 present the numerical characteristics of the one-dimensional normal distribution of export (Table 1) and import flows (Table 2).

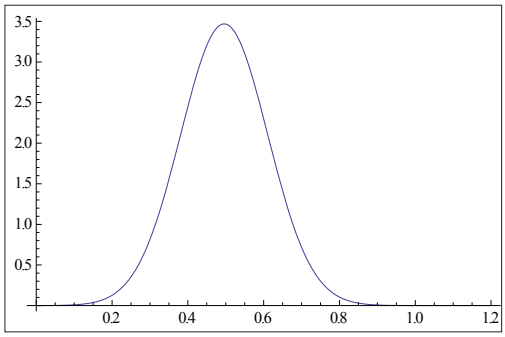
The coefficient of correlation of export-import flows r_{xy} for Mykolaiv region is $r_{xy}=0,9817$ and for Kherson region is $r_{xy}=0,9811$. This indicates the connection between two random variables, which is close to the linear one. Thus, the quantities are dependent and compatible.

Fig. 5 (a) shows a graph of the differential function of export flows for the Mykolaiv region:

$$f(x)=\frac{1}{\sigma_x\sqrt{2\pi}}e^{-\left(\frac{(x-a)^2}{2\sigma_x^2}\right)},\ a=0,4958;\sigma_x=0,1150; \qquad (6)$$

Fig. 5 (b) shows a graph of the differential function of import flows for the Mykolaiv region:

$$f(y)=\frac{1}{\sigma_y\sqrt{2\pi}}e^{-\left(\frac{(y-b)^2}{\sigma_y^2}\right)},\ b=0,6177;\sigma_y=0,1343; \qquad (7)$$



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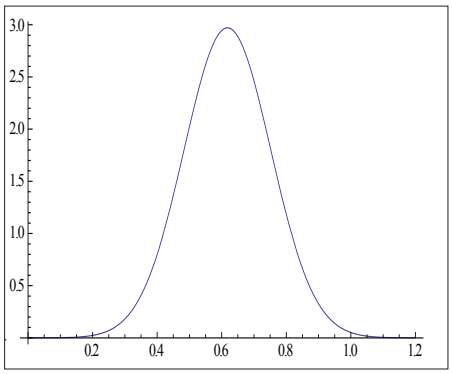


b)

Fig. 5. Differential functions of export (a) and import (b) streams of Mykolaiv region

Table 1

Numerical characteristics of one-dimensional normal distributions of export flows of the regions

Region	Pearson Criteria Terms	One dimensional normal distribution of export regional flows law	Asymmetry	Excess
Mykolaiv	9,0549 < 14.1	$N_{exp}(0,4958;0,1150)$	0,3827	–0,4897
Kherson	2,4158 < 14.1	$N_{exp}(0,1994;0,0374)$	–0,0513	–0,6092

Source: calculated by the authors

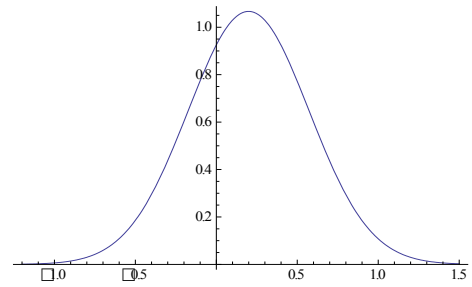
Table 2

Numerical characteristics of one-dimensional normal distributions of import flows of the regions

Region	Pearson Criteria Terms	One dimensional normal distribution of export regional flows law	Asymmetry	Excess
Mykolaiv	9,4833 < 14.1	$N_{imp}(0,6177;0,1343)$	0,5058	–0,3002
Kherson	9,1391 < 14.1	$N_{imp}(0,2682;0,0523)$	0,0728	0,5192

Source: calculated by the authors

Similarly, in Fig. 6 graphs of the differential function of export and import flows of the Kherson region are constructed with values: $a = 0,1994; \sigma_x = 0,0374$; $b = 0,2682; \sigma_y = 0,0523$



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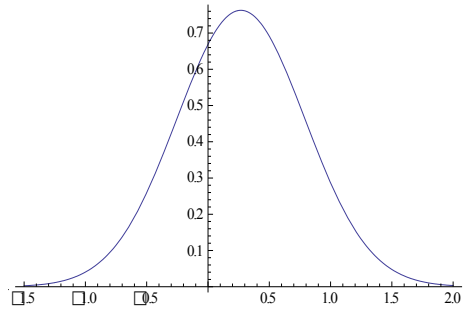

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Fig. 6. Graph of the differential function of import (a) and export (b) streams of the Kherson region

Fig. 7 shows two-dimensional surfaces of the normal distribution, constructed according to formulas (6) and (7), respectively, of export-import flows of Mykolaiv region (Fig. 3 (a)):

$$f(x,y) = \frac{171,85}{\pi} e^{-13,8\left(\frac{(x-0,4958)^2}{0,0132} - 127,1262(x-0,4958)(y-0,6177) + \frac{(y-0,6177)^2}{0,018}\right)} \quad (8)$$

Export-import flows of Kherson region (b):

$$f(x,y) = \frac{1250}{\pi} e^{-13,3\left(\frac{(x-0,1994)^2}{0,0014} - 1003,1595(x-0,1994)(y-0,2682) + \frac{(y-0,2682)^2}{0,0027}\right)} \quad (9)$$

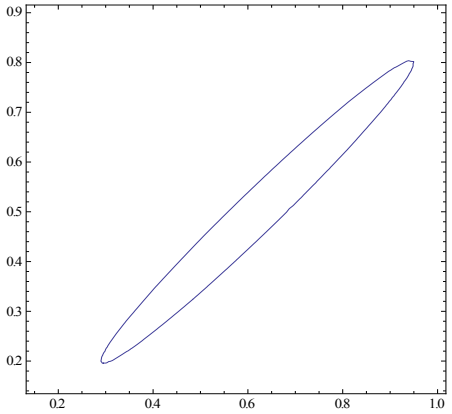
6. Findings

For the diffusion ellipses of export-import flows of Mykolaiv and Kherson regions, we obtain the following equations:

$$\frac{(x-0,4958)^2}{0,0132} - 127,1262(x-0,4958)(y-0,6177) + \frac{(y-0,6177)^2}{0,018} = 0,22359, \quad (10)$$

$$\frac{(x-0,1994)^2}{0,0014} - 1003,1595(x-0,1994)(y-0,2682) + \frac{(y-0,2682)^2}{0,0027} = 0,23956 \quad (11)$$

Figure 8 shows the diffusion ellipses of export-import flows for the Mykolaiv (a) and Kherson (b) regions constructed according to formulas (10) and (11) respectively.



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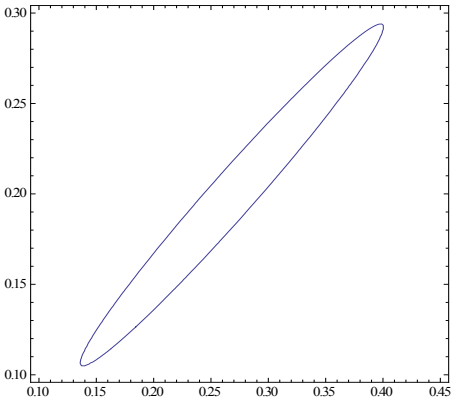
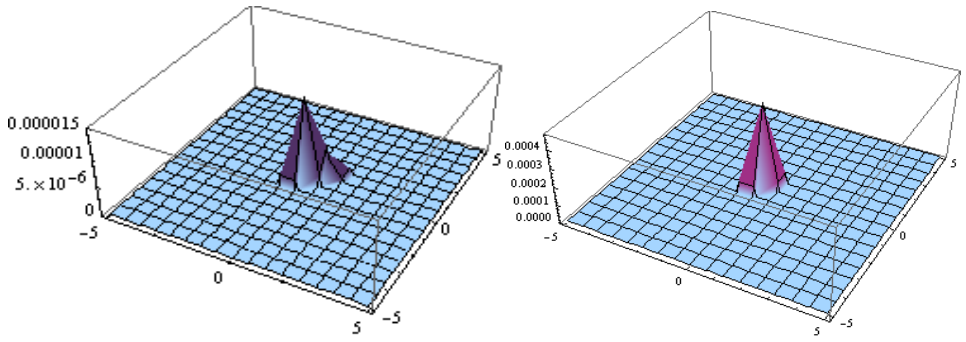


b)

Fig. 8. Ellipses of scattering of export-import streams of the Mykolaiv (a) and Kherson (b) regions



a) b)

Fig. 7. Two-dimensional surfaces of the normal distribution of export-import flows of Mykolaiv (a) and Kherson (b) regions

The crossing of the areas depicted in Fig. 8 is shown in Fig. 9.

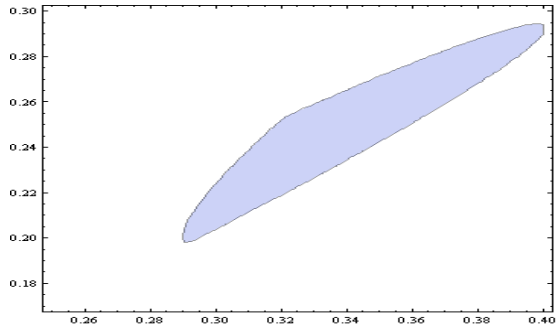


Fig. 9. The crossing of the main splicing ellipses of export-import flows of the Mykolaiv and Kherson regions

The area depicted in Figure 9 can be considered as a common area of permissible risk of regional foreign trade flows in the Mykolaiv and Kherson regions.

Consequently, the study of limits and quantitative analysis of the risk of regional foreign trade operations is reduced to the construction of the area of the crossing of the main splicing ellipses of two-dimensional normal laws of export-import operations.

7. Conclusions

Thus, by constructing diffuse ellipses for regions of different types of development, which will be the areas of the threshold values of these indicators, it will be possible to carry out a comparative assessment of the competitiveness and economic security of the regions. This will allow conducting a systematic analysis of the region's economic development and taking measures both at the local level and at the state level in order to neutralize a number of threats to its economic security.

For other regions of Ukraine, one can find the probability of a two-dimensional random variable reaching the main diffusion ellipse, which can be taken as an estimate of the permissible risk of their foreign trade operations.

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