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Data mining and bifurcation analysis of the risk of money laundering with the involvement of financial institutions

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Abstract. The current trends of globalization, the integration of banks and insurance companies worldwide into a single financial conglomerate, as well as the emergence of new electronic payment instruments, force governments of different countries to search for new approaches to analyse the risks of involvement of financial institutions in money laundering. The research explains how to use the data mining and bifurcation analysis based on the limited information on general indices of a country's characteristics to evaluate the state's resilience to the involvement of its financial institutions in money laundering. The purpose of the article is to develop a scientific and methodological approach to assessing the risk of using financial institutions in money laundering. It is based on the study of the dynamic stability of this risk on the basis of bifurcation theory. Empirical calculations show that for a group of countries, to which Ukraine belongs, the dynamic system is in a non-equilibrium state and is described as a phase portrait "saddle". Therefore, the risk of using financial institutions for money laundering is high in Ukraine, although it is under certain control by the state. However, the calculations show that under conditions of the partial reform of the anti-money laundering system in Ukraine, the system will lose its conditional stability and the corresponding risk will increase even more

Keywords: risk of money laundering, financial institutions, sustainability, data mining, bifurcation theory.

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1. INTRODUCTION

The globalization of the world economy and the formation of the international financial architecture has activated the manufacturing and services sector, and has led to a significant spread of the latest financial instruments (Logan & Esmanov, 2017; Bilan et al., 2019). These transformations have caused an intensive spread of money laundering schemes. This is due to the fact that persons trying to launder money are able to send them in various parts to other countries through financial institutions of one country in a very short period of time. This fact makes it difficult to identify the final recipient of laundered funds (Dmytrov & Medvid, 2017; Khaled & Alasmari, 2012; Leonov et al., 2019). Moreover, the development of information technology in finance creates even greater opportunities for the development of methods and instruments for money laundering (e.g. blockchain technology) (Syniavska, 2019; Syniavska et al. 2019). This leads to the fact that public financial control authorities of any country (developed or developing) are not able to provide comprehensive counteraction to the money laundering (Kolosok & Myroshnychenko, 2015). Thus, according to the UNODC (United Nations Office on Drugs and Crime) assessments for one year, the amount of money laundered worldwide ranges from 0.8 to 2.0 trillion, i.e. 2-5% of the global GDP (according to the United Nations Office on Drugs and Crime). One of the most recent major cases of money laundering is related to Danske Bank in 2017-2018. The bank's branch in Estonia carried out suspicious transactions for 200 billion Euro during 2007-2015 (Jensen, 2018). This indicates that attention should be paid to the issues of combating money laundering both at the international and national levels since only coordinated actions of the regulatory authorities of different states allow determining the origin of criminal funds and their further movement. Moreover, without an effective national anti-money laundering system, it is impossible to carry out a set of covert activities to search and punish criminals. In

addition, it should be noted that financial institutions have recently been the main actors in the money laundering process since they help to hide the source of origin of funds, transform them into various assets, change their storage location, etc.

2. LITERATURE REVIEW

The importance of timely identification of the risk of involvement of financial institutions in money laundering is conditioned by the fact that this risk affects the macroeconomic stability of the state, its investment potential, image, and therefore involvement in international organizations of economic and financial cooperation (Dykha et al., 2019). The pervasive financialization of the economies of the countries worldwide made it impossible to implement any process in the state without the participation of banks, insurance companies, pension funds, etc. (Buriak et al., 2015). Involvement of financial institutions in money laundering decreases the stability of the banking system, causes losses to the country's budget from lost taxes, increases the risk of using the country in terrorist operations (Bilan et al., 2019).

Based on the above, it is important to continue scientific research on the latest approaches to the analysis of the risk of involvement of financial institutions in money laundering. However, it should be noted that in modern scientific literature, risk assessment is given considerable attention as the role of risks in the development of economic processes is of prime importance. Thus, Amrin (2019) studied characteristics of business entities and corporate governance on risk disclosure practices; Belás et al. (2018) identified financial risk factors; Bialas (2016), Prince (2018) observed the general aspects of risk management. It is necessary to highlight studies related to the risks of functioning of banks since the risk of money laundering is one of the most threatening to their reputation. Subeh & Yarovenko (2017) identified the risks related to data mining of operations with card accounts of bank clients, Sysoyeva & Buriak (2014) developed provisions on regulating system risks in the banking sector, and Bagmet et al. (2015) studied the bank-insurance integration risks.

There are some studies about assessing the money laundering risks, but the authors of these studies focus on the probability of this risk as a whole, rather than on its carriers (Kostyuchenko et al., 2018). Certain preliminary studies that deal with the identification of financial institutions as actors of money laundering have been carried out by Boyko & Roienko (2014), where they identify insurance companies as active carriers of the risk of using their own services to launder money.

Having considered the features of risk assessment and management in general, as well as the specific nature of the risk of involvement of financial institutions in money laundering in particular, we proceed to the development of the proprietary methodology.

3. METHODOLOGY

It is proposed to use data mining tools within the framework of the methodology for assessing the risk of using financial institutions for money laundering. Thus, the authors suggest using a combination of the following methods: correlation analysis and the scree test to detect multicollinearity of the array of input indicators, followed by the selection of the most relevant ones among them; analysis of variance to substantiate the number of homogeneous groups of the countries under consideration in terms of the risk of involvement of financial institutions in money laundering; clustering of the countries in terms of the risk under study based on the k-means method, where it was proposed to choose Euclidean distances as a grouping indicator, which makes it possible to form homogeneous groups of countries in terms of the risk of involvement of financial institutions in money laundering; bifurcation analysis of the study of the dynamic stability of the risk of involvement of financial institutions in money laundering, which will identify the type of phase portrait (stable or unstable) and appropriate ways to overcome the risk under study; nonlinear

multivariate regression analysis to determine the parameters of the dependence of the studied risk of factorial features through linearisation and the use of the least squares method.

The result of implementing the proposed methodology should be a phase portrait of the dynamic system of the risk level of the established clusters of countries based on the differential calculus. The practical implementation of the proposed methodology involves the following sequence of stages.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Formation of input statistical base of the study, verification of the multicollinearity of the input indicators

Within the first stage, the input statistical base of the study is formed and the multicollinearity of the input indicators is further verified by applying correlation analysis. The latter will allow excluding those indicators that can be neglected and, thus, simplify the calculations (Kozmenko & Roienko, 2013; Malyarets et al., 2019). The relevance of a reasonable determination of each of the characteristics of the process under study is associated with obtaining adequate results (Bublyk et al., 2017). Thus, regardless of what economic and mathematical tools will be used, the reliability of the results will be low if the input information does not characterize the features of the studied risk (Kozmenko et al., 2009; Vasylyeva et al., 2016). Thus, the risk of using financial institutions for money laundering is characterized through a spatial analysis of data for 105 countries in 2018. The following list of indicators is selected as the assessment indicators: GDP per capita (current LCU); bank secrecy; claims on central government, etc. (% GDP); internally displaced persons, new displacement associated with conflict and violence (number of cases); corruption perceptions index; global terrorism index; happiness score; prosperity index. Taking into account the characteristics of the selected input indicators, we note that authors described the relevance of each of them in more detail in previous work (Lyeonov et al., 2019).

A fragment of the numerical data regarding the characteristics of the risk of using financial institutions for money laundering, in the context of the countries, is shown in Table 1.

Table 1

Statistics characterizing the risk of using financial institutions for money laundering

No	Country	GDP per capita (current LCU)	Bank secrecy	Claims on central government, etc. (% GDP)	Internally displaced persons, new displacement associated with conflict and violence (number of cases)	Corruption perceptions index	Global Terrorism Index	Happiness score	Prosperity Index
1	Afghanistan	40016,43	0,00	-5,92	474000,00	15,00	9,44	3,79	40,03
2	Angola	691920,70	3,00	13,14	0,00	19,00	0,15	3,80	44,01
3	Albania	540458,06	7,00	26,34	0,00	38,00	1,49	4,64	60,05
4	United Arab Emirates	149466,52	7,00	4,59	0,00	71,00	0,21	6,65	66,70
5	Argentina	238496,70	7,00	21,91	0,00	39,00	0,81	6,60	62,70
6	Armenia	1900357,11	3,00	6,40	0,00	35,00	2,37	4,38	57,16
7	Australia	71333,34	7,00	2,97	0,00	77,00	3,09	7,28	78,08

8	Austria	41965,83	7,00	16,10	0,00	75,00	1,52	7,01	76,67
9	Azerbaijan	7111,34	7,00	-2,25	0,00	31,00	1,15	5,23	55,42
…	…	…	…	…	…	…	…	…	…
98	Tunisia	8445,71	3,00	11,33	0,00	42,00	4,62	4,80	57,08
99	Turkey	38453,23	7,00	8,03	0,00	40,00	7,52	5,50	58,23
100	Tanzania	2086947,98	3,00	0,00	0,00	36,00	3,41	3,35	54,77
101	Uganda	2131244,03	3,00	7,95	1300,00	26,00	4,32	4,08	50,98
102	Ukraine	70210,35	3,00	23,98	21000,00	30,00	6,56	4,10	53,65
103	Uruguay	490945,23	7,00	7,77	0,00	70,00	0,78	6,45	69,67
104	South Africa	82017,24	7,00	0,00	0,00	43,00	4,09	4,83	61,33
105	Zimbabwe	1079,61	0,00	0,00	0,00	22,00	0,20	3,88	51,80

In order to substantiate the expediency of taking into account all of the above indicators, it becomes necessary to conduct a correlation analysis. Thus, using the MS Excel tools of the Analysis/Correlation package, we construct a correlation matrix of the dependence between the indicators that characterise the risk of using financial institutions for money laundering (Table 2) (Zakharkin et al., 2018).

Table 2

Characteristic of the relationship between indicators of the risk of using financial institutions for money laundering

	GDP per capita (current LCU)	**Bank secrecy**	**Claims on central government, etc. (% GDP)**	**Internally displaced persons, new displacement associated with conflict and violence (number of cases)**	**Corruption perceptions index**	**Global terrorism index**	**Happiness score**	**Prosperity index**
GDP per capita (current LCU)	1,00							
Bank secrecy	0,11	1,00						
Claims on central government, etc. (% GDP)	-0,12	0,28	1,00					
Internally displaced persons, new displacement associated with conflict and violence (number of cases)	0,03	-0,25	-0,11	1,00				
Corruption perceptions index	-0,09	0,61	0,12	-0,24	1,00			
Global terrorism index	0,08	-0,11	0,01	0,48	-0,27	1,00		
Happiness score	-0,01	0,58	0,16	-0,21	0,72	-0,21	1,00	
Prosperity index	-0,01	0,66	0,15	-0,34	0,90	-0,37	0,84	1,00

Analysis of the data in Table 2 shows that there is significant multicollinearity in three cases: between the prosperity index and corruption perceptions index at the level of 0.9 unit fraction, between the prosperity index and the happiness score at the level of 0.84 unit fraction, and between happiness score and corruption perceptions index at the level of 0.72. In order to avoid unnecessary complication of the model by

simultaneously incorporating collinear indicators, it is proposed to exclude the prosperity index from further calculations as an irrelevant indicator, which will eliminate the multicollinearity phenomenon in the two above cases and thereby increase the adequacy of the obtained calculations. Despite the fact that the correlation coefficient between happiness score and corruption perceptions index indicates a tight link, it is reasonable not to consider both indicators in terms of economic theory. Thus, the relevance of entering the corruption perceptions index into the final data set is explained by the fact that corruption is the basis for any money laundering scheme since it minimizes control actions, possible resistance and complications of financial transactions (Džunić & Golubović, 2018; Mujtaba et al., 2018). The spread of corruption in all spheres of activity of business entities and government agencies helps to minimize the risk of exposing fraudulent transactions (Remeikienė et al., 2018). Proceeding from the fact that financial institutions are only a part of the money laundering mechanism and its full scheme includes enterprises, government agencies and business entities, it is necessary to investigate corruption at all these levels (Mackevičius, 2012). It has been confirmed by numerous studies on corruption. Castillo (2018) studies corruption in state-owned enterprises; Saputra (2019) analyses the relationship between corruption and trade in developed and developing countries; Dheera-aumpon (2017) identifies peculiar features of corruption in the process of obtaining a bank loan; Nguedie (2018) focuses on the relationship between corruption and investment inflow and outflow. Corruption also affects innovative activities, where its effect is interpreted in different ways, however, noting that, eventually, it is a very negative phenomenon (Pirtea et al., 2019).

4.2. Clustering of the world countries in terms of assessing the risk of using financial institutions for money laundering

At the second stage of the proposed approach, the countries are grouped into 10 clusters by the k-means method, followed by the characterization of each cluster using statistical indicators (Euclidean distances from the grouping centre, arithmetic mean) and analysis of variance. In order to implement this stage, it is suggested to use the Statistica toolkit: 1) the Data Package, the Standardise tab – to bring the statistical base of the study into a comparable form; 2) Analysis Package, Multivariate Analysis tab, Cluster Analysis – for direct selection of one-year typical groups of countries in terms of the issue under study. The obtained results are summarized in graphical form (Figure 1–4), indicating both the number of countries and members of each cluster and the Euclidean distance from the centre of the grouping as a defining metric of this grouping of countries.

	Members of Cluster Number 1 (Spreadsheet claster analys norm. sta) and Distances from Respective Cluster Center Cluster contains 12 cases
	Distance
Azerbaijan	0,394627
Bulgaria	0,466078
Bahrain	0,162510
Greece	0,414555
Kazakhstan	0,317136
Kuwait	0,380028
Lebanon	0,841416
Mexico	0,614792
Malaysia	0,218749
Panama	0,544193
Saudi Arabia	0,728703
South Africa	0,335480

Figure 1. Components and characteristics of the first cluster in terms of Euclidean distances

	Cluster 2 (15)
	Distance
Belarus	0,369861
Bolivia	0,373186
Ecuador	0,273635
Guatemala	0,422261
Honduras	0,309235
Jamaica	0,317967
Jordan	0,530059
Morocco	0,549014
Moldova	0,267816
Montenegro	0,328054
Nicaragua	0,375821
Peru	0,300763
Serbia	0,351423
Tajikistan	0,457664
Trinidad and Tobago	0,302127

	Cluster 3 (3)
	Distance
Colombia	0,886995
Indonesia	1,297079
Paraguay	0,666971

	Cluster 4 (6)
	Distance
China	0,494112
India	0,562978
Nigeria	0,646602
Pakistan	0,608005
Thailand	0,603396
Turkey	0,275877

Figure 2. Components and characteristics of the second, third and fourth clusters in terms of Euclidean distances

	Cluster 5 (5)
	Distance
Afghanistan	0,724983
Central African Republic	0,699854
Ethiopia	0,371074
Iraq	1,419047
Philippines	0,674388

	Cluster 6 (8)
	Distance
Burundi	0,558283
Bangladesh	0,289735
Algeria	0,607918
Kenya	0,265006
Chad	0,267679
Tunisia	0,367433
Uganda	0,339007
Ukraine	0,390629

	Cluster 7 (8)
	Distance
Burkina Faso	0,392643
Cameroon	0,389898
Libya	0,457457
Mali	0,169020
Mozambique	0,197302
Niger	0,360982
Nepal	0,291781
Sudan	0,297775

Figure 3. Components and characteristics of the fifth, sixth and seventh clusters in terms of Euclidean distances

The analysis of the clusters allows asserting that the grouping is quite consistent with the general level of money laundering in the countries from the same cluster. Thus, the smallest cluster includes Colombia, Indonesia and Paraguay, countries characterized by money laundering following the production and transportation of drugs. The next largest cluster is a group of five countries: Afghanistan, Central African Republic, Ethiopia, Iraq and the Philippines. A common feature of these countries is laundering of money obtained from terrorism. The largest cluster of the ten clusters is a group of 22 countries, which includes the most developed countries, in which illegal incomes are fragmented through various financial institutions.

A comprehensive analysis of statistical indicators using standardised average values and Euclidean distances allows for more comprehensive characterisation of the results of clustering of countries in the context of assessing the risk of using financial institutions for money laundering and understanding the essence of each of the groups formed (Figure 5 and Figure 6). Thus, the smaller the Euclidean distance from the grouping centre for each cluster, the more the countries in a given cluster are similar in the methods and levels of money laundering.

	Cluster 8 (15)
	Distance
Angola	0,500317
Armenia	0,235640
Georgia	0,450898
Ghana	0,624891
Guinea	0,453359
Cambodia	0,676347
Liberia	0,277553
Sri Lanka	0,300380
Lesotho	0,469587
Madagascar	0,380328
Rwanda	0,470414
Senegal	0,289904
Sierra Leone	0,525841
Tanzania	0,376291
Zimbabwe	0,501852

	Cluster 9 (11)
	Distance
Albania	0,433295
Argentina	0,368021
Brazil	0,593268
Cyprus	0,448097
Dominican Republic	0,631330
Spain	0,337848
Croatia	0,455263
Hungary	0,376798
Italy	0,789955
Poland	0,544404
Qatar	0,516841

	Cluster 10 (8)
	Distance
United Arab Emirates	0,400288
Australia	0,211255
Austria	0,326953
Belgium	0,546816
Canada	0,308768
Switzerland	0,498003
Chile	0,632283
Czech Republic	0,432898
Germany	0,360864
Denmark	0,501568
Estonia	0,601590
Finland	0,268334
France	0,678409
United Kingdom	0,811028
Ireland	0,306179
Iceland	0,661269
Israel	0,529231
Japan	0,483613
Netherlands	0,331685
New Zealand	0,479845
Sweden	0,291998
Uruguay	0,339304

Figure 4. Components and characteristics of the eighth, ninth and tenth clusters in terms of Euclidean distances

Variable	Cluster Means (Spreadsheet claster analys norm. sta)									
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster .8	Cluster 9	Cluster 10
GDP per capita (current LCU)	-0,062	-0,266	4,919	-0,252	-0,068	-0,205	-0,242	-0,010	-0,202	-0,101
Bank Secrece	0,933	-1,020	0,468	0,701	-1,299	-0,854	-1,246	-0,508	0,807	0,933
Claims on central government, etc. (% GDP)	-0,629	-0,488	-0,731	0,571	-0,538	0,650	-0,439	-0,398	1,791	0,040
Internally displaced persons, new displacement associated with conflict and violence (number of cases)	-0,241	-0,250	0,015	0,155	3,987	-0,200	-0,078	-0,251	-0,251	-0,251
Corruption Perceptions Index	-0,285	-0,406	-0,494	-0,401	-0,973	-0,787	-0,845	-0,474	0,187	1,653
Global Terrorism Index	0,045	-0,848	0,561	1,682	1,817	0,859	1,043	-0,703	-0,793	-0,210
Happy Planet Index	0,251	0,166	0,233	-0,104	-1,071	-0,916	-0,781	-1,242	0,335	1,286

Figure 5. Average values of the indicators characterising the risk of using financial institutions for money laundering

Cluster Number	Euclidean Distances between Clusters (Spreadsheet claster analys norm.sta) Distances below diagonal Squared distances above diagonal									
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
No. 1	0,000	0,671	3,631	0,644	4,032	1,018	1,032	0,708	0,975	0,763
No. 2	0,819	0,000	4,461	1,531	3,861	0,794	0,679	0,335	1,274	1,431
No. 3	1,905	2,112	0,000	4,269	6,758	4,492	4,436	4,172	5,012	4,628
No. 4	0,802	1,237	2,066	0,000	3,032	0,577	0,847	1,373	1,190	1,464
No. 5	2,008	1,965	2,600	1,741	0,000	2,876	2,466	3,605	5,424	5,690
No. 6	1,009	0,891	2,120	0,760	1,696	0,000	0,201	0,557	1,330	2,217
No. 7	1,016	0,824	2,106	0,920	1,570	0,449	0,000	0,576	2,129	2,444
No. 8	0,842	0,579	2,042	1,172	1,899	0,747	0,759	0,000	1,356	1,919
No. 9	0,987	1,129	2,239	1,091	2,329	1,153	1,459	1,164	0,000	0,926
No. 10	0,874	1,196	2,151	1,210	2,385	1,489	1,563	1,385	0,962	0,000

Figure 6. Euclidean distances

An analysis of variance, the results of which are presented in Figure 7, is a significant addition and justification of the expediency of the clustering (Skare & Porada-Rochoń, 2019). In terms of each indicator (GDP per capita (current LCU); bank secrecy; claims on central government, etc. (% GDP); internally displaced persons, new displacement associated with conflict and violence (number of cases); corruption perceptions index; global terrorism index; happiness score), we observe that the sum of squared deviations from the sample mean within each group (within SS) is significantly less than the sum of squared deviations without taking into account group affiliation (between SS). In addition, using the Fisher's ratio test and the closeness of the probability of accepting the hypothesis on the coincidence of intragroup variance with the total variance to zero, it can be argued that the difference between the averages for each group and the average as a whole for the considered population is statistically significant (from 12 to 52). Therefore, the values of Table 7 indicate the feasibility of grouping the countries according to the selected set of indicators and confirms our hypothesis.

Variable	Analysis of Variance (Spreadsheet claster analysis norm.sta)					
	Between SS	df	Within SS	df	F	signif.
GDP per capita (current LCU)	75,582	9,000	28,418	95,000	28,075	0,000
Bank Secrece	86,550	9,000	17,450	95,000	52,356	0,000
Claims on central government, etc. (% GDP)	55,944	9,000	48,056	95,000	12,288	0,000
Internally displaced persons, new displacement associated with conflict and violence (number of cases)	84,632	9,000	19,368	95,000	46,125	0,000
Corruption Perceptions Index	84,390	9,000	19,610	95,000	45,425	0,000
Global Terrorism Index	75,161	9,000	28,839	95,000	27,510	0,000
Happy Planet Index	79,462	9,000	24,538	95,000	34,183	0,000

Figure 7. Analysis of variance

4.3. Selection of relevant indicators for assessing the dynamic stability of the risk of using financial institutions for money laundering

Within the framework of the third stage, the principal component method was used to justify the feasibility of accounting four (not seven) factors for assessing the dynamic stability of the risk of using financial institutions for money laundering: bank secrecy; Internally displaced persons, new displacement associated with conflict and violence (number of cases); corruption perceptions index; global terrorism index (Vechkinzova et al., 2019).

Table 3

Description of the sixth cluster countries including Ukraine

Country	GDP per capita (current LCU)	Bank Secrecy	Claims on central government, etc. (% GDP)	Internally displaced persons, new displacement associated with conflict and violence (number of cases)	Corruption Perceptions Index	Global Terrorism Index	Happiness score	Risk of money laundering
Burundi	553447,80	0,00	18,29	14000,00	22,00	5,64	2,90	0,6750
Bangladesh	119986,54	0,000001	14,63	6000	28,00	6,18	4,61	0,3679
Algeria	457584,95	0,000001	19,26	0,000001	33,00	3,97	5,87	1,0000
Kenya	155924,49	3	9,64	24000	28,00	6,17	4,55	1,0000
Chad	389937,27	3	13,03	5800	20,00	5,27	3,94	0,5708
Tunisia	8445,71	3,00	11,33	0,00	42,00	4,62	4,80	0,9991
Uganda	2131244,03	3,00	7,95	1300,00	26,00	4,32	4,08	1,0000
Ukraine	70210,35	3,00	23,98	21000,00	30,00	6,56	4,10	-

Thus, based on the data of the above indicators in the context of such countries as Burundi, Bangladesh, Algeria, Kenya, Chad, Tunisia, Uganda, Ukraine (Table 3), we will build scree plot for the eigenvalues of the correlation matrix of the input data for assessing the risk of using financial institutions for money laundering (Figure 8).

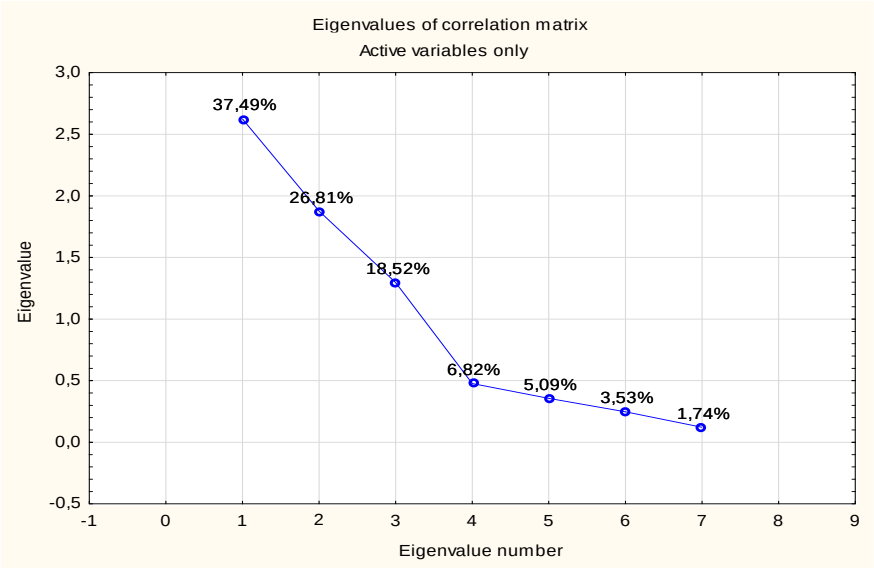

Figure 8. Scree plot for the eigenvalues of the correlation matrix of the input data

The analysis of the eigenvalues of the correlation matrix of the input data for assessing the risk of using financial institutions for money laundering (Figure 8, Figure 9) suggests that it is feasible to take the first three factors in order to select relevant indicators since they provide at least 80% (factor 1 – 37.49%, factor 2 – 26.81%, factor 3 –18.52%) of the effective feature variations.

Value number	Eigenvalues of correlation matrix and related statistics Active variables only			
	Eigenvalues	% total dispersion	Cumulative Eigenvalues	Cumulative %
1	2,62	37,49	2,62	37,49
2	1,88	26,81	4,50	64,30
3	1,30	18,52	5,80	82,82
4	0,48	6,82	6,27	89,63
5	0,36	5,09	6,63	94,72
6	0,25	3,53	6,88	98,26
7	0,12	1,74	7,00	100,00

Figure 9. Eigenvalues of the correlation matrix and derivative statistical indicators

Therefore, based on the eigenvalues of the correlation matrix of the input data for assessing the risk of using financial institutions for money laundering, in the context of the first three factors, as well as the contribution of the risk assessment variables (Figure 10), we form Table 4.

Variable	Variable contributions			
	Factor 1	Factor 2	Factor 3	Factor 4
GDP per capita (current LCU)	0,070	0,323	0,030	0,111
Bank Secrece	0,000	0,067	0,571	0,202
Claims on central government, etc. (% GDP)	0,077	0,174	0,150	0,568
Internally displaced persons, new displacement associated with conflict and violence (number of cases)	0,296	0,000	0,060	0,000
Corruption Perceptions Index	0,091	0,225	0,144	0,032
Global Terrorism Index	0,325	0,006	0,026	0,061
Happiness Score	0,141	0,206	0,020	0,027

Figure 10. Contribution of risk assessment variables

The data in Table 4 reflect the logic of calculating the weighted arithmetic simple value of the effect made by indicators for assessing the risk of using financial institutions for money laundering on value of this risk by calculating the sum of the products of weighting coefficients of factors (eigenvalues of the correlation matrix of input factors). The result of these calculations is demonstrated in the column "Weighted effect of indicators" in Table 4.

Table 4

Intermediate calculations of the relevance of indicators for assessing the risk

Indices / Weighting coefficients	**Factor 1**	**Factor 2**	**Factor 3**	**Weighted effect of indices**
	37,4908	26,8064	18,5182	
GDP per capita (current LCU)	0,0701	0,3229	0,0300	11,8408
Bank Secrecy	0,0000	0,0665	0,5708	**12,3531**
Claims on central government, etc. (% GDP)	0,0770	0,1736	0,1497	10,3147
Internally displaced persons, new displacement associated with conflict and violence (number of cases)	0,2958	0,0001	0,0603	**12,2091**
Corruption perceptions index	0,0910	0,2250	0,1437	**12,1059**
Global terrorism index	0,3248	0,0061	0,0259	**12,8214**
Happiness score	0,1411	0,2059	0,0195	11,1705

Based on the data in Table 4, it can be argued that at least 12% of the total effect on the formation of an effective indicator (the risk of using financial institutions for money laundering) is made by four

indicators: bank secrecy; internally displaced persons, new displacement associated with conflict and violence (number of cases); corruption perceptions index; global terrorism index. These indicators are proposed to be used for further research.

4.4. Investigating the nature of the dynamic stability of the group of countries to which ukraine belongs in the context of the risk of using financial institutions for money laundering

At the fourth stage, a bifurcation analysis of a group of countries, to which Ukraine belongs, was carried out and the expediency of describing a dynamic system in a non-equilibrium state in terms of the risk of using Ukrainian financial institutions for money laundering in the form of a phase portrait "saddle" was proved. This stage is complex and contains a number of intermediate steps (Zarutska et al., 2018).

Specifications of the functional dependence of the risk of using financial institutions for money laundering on non-linear factor indicators.

This step is preparatory to the further bifurcation analysis of the group of countries to which Ukraine belongs. In order to implement this step, we use MS Excel package, Analysis tab, Regression tab, which allow testing the hypothesis (using the Student's test) about the statistical significance of regression coefficients in relation to variables that display linear, quadratic, logarithmic, trigonometric, or hyperbolic functional dependence (Kuzmenko & Koibichuk, 2018). Choosing the largest t Stat among the calculated values of t Stat presented in Table 5, we determine the specification of dependencies for four relevant factors: bank secrecy; internally displaced persons, new displacement associated with conflict and violence (number of cases); corruption perceptions index; global terrorism index. Therefore, the bank secrecy index is proposed to be described by means of a hyperbolic function (the corresponding Student test is 1.07 modulo), internally displaced persons, new displacement associated with conflict and violence (number of cases) – by the logarithmic function (the corresponding criterion t Stat is 330.88 modulo). In the context of the following two indicators, it is expedient to use trigonometric dependence (sinusoid), as evidenced by the corresponding calculated values of the Student's test at the level of 0.63 and 0.42 (Valaskova et al., 2018).

Table 5

Statistical significance of the functional dependence specification regarding the risk assessment

t Stat	**Bank secrecy**	**Internally displaced persons, new displacement associated with conflict and violence (number of cases)**	**Corruption perceptions index**	**Global terrorism index**
Intercept	6,8670	439,9692	0,3781	-0,3980
X	-	48,4797	0,3308	-0,4002
x2	-	87,8936	-0,2923	0,3992
Lnx	-	**-330,8753**	-0,3662	0,3995
Sinx	-	227,8737	**0,6285**	**0,4235**
1/x	**-1,0655**	-339,1088	-0,3987	0,3972

The econometric model of nonlinear multivariate regression dependence of the risk of using financial institutions for money laundering on relevant factors of its formation.

Having formed the indicator of the risk of using financial institutions for money laundering as an effective indicator, and factorial indicators – the inverse dependence of the bank secrecy index, the natural logarithm of the internally displaced persons index, new displacement associated with conflict and violence (number of cases), sinus of corruption perceptions index and global terrorism index, we use the MS Excel

toolkit Analysis, Regression package, which will be used to determine the coefficients of the sought econometric model using the least-squares method (Table 6) (Kuzmenko & Kyrkach, 2014; Krykliy & Ryabichenko, 2012).

Table 6

Results of statistical analysis of the dependence regarding the risk assessment

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	0,26242	0,82417	0,31840	0,80376	-10,20963	10,73447
1/x	1,4240E-07	4,9720E-07	0,2864	0,8224	-6,1752E-06	6,4600E-06
Ln	-0,01024	0,01614	-0,63440	0,64010	-0,21535	0,19487
Sin	-0,00824	0,22109	-0,03727	0,97629	-2,81746	2,80098
Sin	-0,61356	0,83974	-0,73065	0,59829	-11,28346	10,05635
x1x2x3x4	6,0119E-08	6,0685E-08	0,9907	0,5030	-7,1096E-07	8,312E-07

Based on the data of the «*Coefficients*» column in Table 6, we will construct the econometric model of the non-linear multifactorial regression dependence of the risk of using financial institutions for money laundering on relevant factors of its formation:

$$f(bs, id, c, gt) := 0.2624 + 1.4240 \cdot 10^{-7} \cdot \frac{1}{bs} - 0.0102 \cdot \ln(id) - 0.0082 \cdot \sin(c) - 0.6136 \cdot \sin(gt) + 6.0119 \cdot 10^{-8} \cdot bs \cdot id \cdot c \cdot gt \quad (1)$$

where bs – bank secrecy;

id – internally displaced persons, new displacement associated with conflict and violence (number of cases);

c – corruption perceptions index;

gt - global terrorism index.

Construction of a phase portrait of a dynamic system of the risk of using financial institutions of Ukraine for money laundering.

The implementation of this step involves preliminary calculations in the context of differential calculus, namely the determination of partial derivatives of the function regarding the dependence of the risk of using Ukrainian financial institutions for money laundering on its formation factors, which serve as a basis to study the dynamic stability of the system (formulas 2) (Kozmenko & Kuzmenko, 2013). This step is implemented using MathCAD capabilities. Based on the considered function (1), we will model non-linear differential equations characterizing the behaviour of the dynamic system of the indicator of the risk of using Ukrainian financial institutions for money laundering:

$$\begin{aligned} &\frac{d}{dbs} f(bs, id, c, gt) \rightarrow 6.0119e\text{-}8 \cdot c \cdot gt \cdot id - \frac{1.424e\text{-}7}{bs^2} \\ &\frac{d}{did} f(bs, id, c, gt) \rightarrow 6.0119e\text{-}8 \cdot bs \cdot c \cdot gt - \frac{0.0102}{id} \\ &\frac{d}{dc} f(bs, id, c, gt) \rightarrow -0.0082 \cdot \cos(c) + 6.0119e\text{-}8 \cdot bs \cdot gt \cdot id \\ &\frac{d}{dgt} f(bs, id, c, gt) \rightarrow -0.6136 \cdot \cos(gt) + 6.0119e\text{-}8 \cdot bs \cdot c \cdot id \end{aligned} \quad (2)$$

The above differential equations (2) establish relationships between independent variables bs (bank secrecy), id (internally displaced persons, new displacement associated with conflict and violence (number of cases)), c (corruption perceptions index), gt (global terrorism index) and their derivatives ($\frac{d}{dbs}f(bs,id,c,gt), \frac{d}{did}f(bs,id,c,gt), \frac{d}{dc}f(bs,id,c,gt), \frac{d}{dgt}f(bs,id,c,gt)$).

A non-linear approach based on the bifurcation theory makes it possible to construct a "phase portrait" of the indicator of the risk of using the Ukrainian financial institutions for money laundering, i.e. to reflect trajectories on the selected plane of the phase space (Vasilyeva et al., 2019).

The phase portrait based on differential equations can be built using the mathematical software MathCad:

$$
\begin{aligned}
&\text{Faza}(bs0, id0, c0, gt0, dt, N) := \\
&\quad \left(bs_0 \leftarrow bs0 \quad id_0 \leftarrow id0 \quad c_0 \leftarrow c0 \quad gt_0 \leftarrow gt0\right) \\
&\quad \text{for } k \in 0..N \\
&\qquad ff \leftarrow f\left(bs_k, id_k, c_k, gt_k\right) \\
&\qquad bs_{k+1} \leftarrow \left[bs_k + dt\cdot\left[6.0119\text{e-}8\cdot c_k\cdot gt_k\cdot id_k - \frac{1.424\text{e-}7}{\left(bs_k\right)^2}\right]\right] \\
&\qquad id_{k+1} \leftarrow \left[id_k + dt\cdot\left(6.0119\text{e-}8\cdot bs_k\cdot c_k\cdot gt_k - \frac{0.0102}{id_k}\right)\right] \\
&\qquad c_{k+1} \leftarrow \left[c_k + dt\cdot\left(-0.0082\cdot\cos\left(bs_k\right) + 6.0119\text{e-}8\cdot bs_k\cdot gt_k\cdot id_k\right)\right] \\
&\qquad gt_{k+1} \leftarrow \left[gt_k + dt\cdot\left(-0.6136\cdot\cos\left(gt_k\right) + 6.0119\text{e-}8\cdot bs_k\cdot bs_k\cdot id_k\right)\right] \\
&\quad (bs \quad id \quad c \quad gt)
\end{aligned}
\tag{3}
$$

According to the theory of bifurcation and the variety of phase portraits of two-dimensional space, we will characterise the indicator of the risk of using Ukrainian financial institutions for money laundering:

$$
\begin{aligned}
(bs1 \quad id1 \quad c1 \quad gt1) &:= \text{Faza}(3, 21000, 30, 6.56, 0.001, 10000) \\
(bs10 \quad id10 \quad c10 \quad gt10) &:= \text{Faza}(3, 14000, 22, 5.64, 0.01, 10000) \\
(bs13 \quad id13 \quad c13 \quad gt13) &:= \text{Faza}(3, 0.0001, 28, 6.181, 0.01, 1000000) \\
(bs58 \quad id58 \quad c58 \quad gt58) &:= \text{Faza}(3, 5800, 20, 6.169, 0.01, 10000) \\
(bs98 \quad id98 \quad c98 \quad gt98) &:= \text{Faza}(3, 0.0001, 42, 4.62, 0.01, 1000000)
\end{aligned}
\tag{4}
$$

We further investigate the “phase portrait” (Fig. 11), which shows the saddle-type bifurcation. This type of bifurcation indicates an unstable state of the system, i.e. a significant change in the parameter and a fixed value of another parameter leads to a non-equilibrium state of this system.

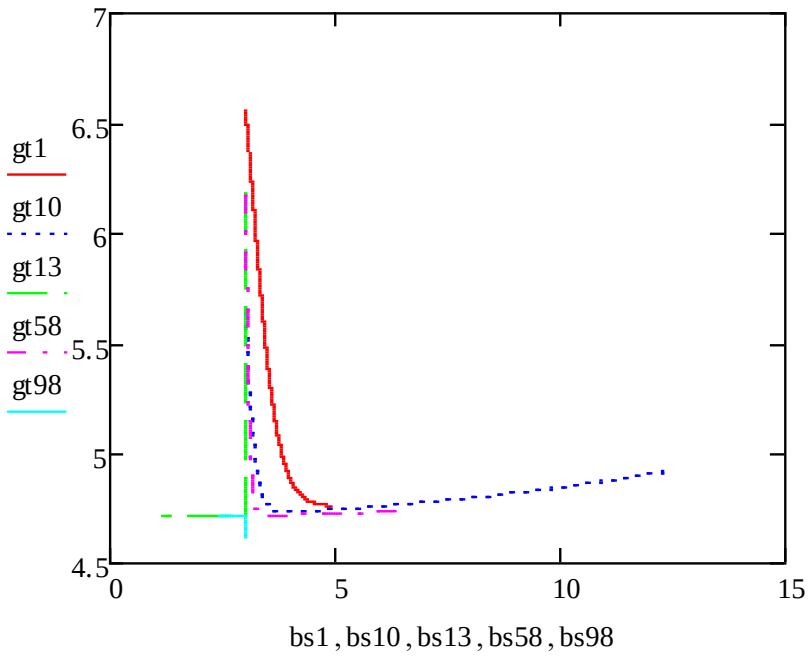

Figure 11. Phase portrait "saddle" in the context of the use of Ukrainian financial institutions for money laundering

Therefore, analysing the risk of using financial institutions of Ukraine for money laundering, it can be argued that it is in constant dynamics: from decrease to increase and vice versa.

5. CONCLUSION

Nowadays, for every state, one of the highest priorities of social development is to achieve a high level of economic security. The complexity of economic security that allows, subject to its achievement, to form all the necessary prerequisites for the sustainable development of the state, while providing a non-recurring trend in the indicators of socioeconomic development (Gagarina et al., 2019; Bilan et al., 2020). The policy of ensuring the state's economic security should include both methods of stimulating financial, social, environmental and other processes in the state, and instruments for effective counteraction to destructive factors (Lewandowski, 2016).

The illegal incomes that flow through a country's financial system significantly affect its economic security and can cause not only the loss of financial stability of banks, insurers, etc., but also lead to an increase in crime and terrorist attacks in the state. The study suggests that the tools for the state's economic security should be based on a detailed study of the processes that provide it or may violate it (Kamaliah et al., 2018; Katan et al., 2019). Thus, the anti-money laundering system should be able to quickly adapt and change since the results of the scientific and methodological approach to assessing the risks of using Ukrainian financial institutions for money laundering indicate its low efficiency. This is confirmed by the resulting phase portrait "saddle" of the dynamic system of the risk of money laundering. Thus, the existing system of state financial control in Ukraine is not able to contain the risk under study and prevent criminals from using other schemes, after minimizing the risk of money laundering. The investigation of effective measures to prevent money laundering, which will be able to eliminate the potential opportunities of these crimes, based on data mining, becomes relevant.

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