USING FACTOR ANALYSIS TO DETERMINE REPRESENTATIVE INDICATORS IN THE FINANCIAL SPHERE OF ECONOMIC SECURITY

UTILIZAÇÃO DA ANÁLISE FATORIAL PARA DETERMINAR INDICADORES REPRESENTANTES NA ESFERA FINANCEIRA DA SEGURANÇA ECONÔMICA

USO DEL ANÁLISIS FACTORIAL PARA DETERMINAR INDICADORES REPRESENTATIVOS EN EL ÁMBITO FINANCIERO DE LA SEGURIDAD ECONÓMICA

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ABSTRACT

 The purpose of the study is to adapt the factor analysis method for the determination of representative indicators. Within the article, the algorithm for applying factor analysis according to the goals of determining representative indicators is revealed. The authors use the method of factor analysis and the method of principal components, through which a sample of seven economic security indicators for the period from 2007 to 2020 is analyzed. The analysis is carried out using the IBM SPSS Statistics data analysis software platform. Based on the results of the analysis, a conclusion is made about the applicability of the factor model, the resulting factors are assessed, and an approach to the choice of a representative indicator based on factor loading is proposed. The main disadvantage of the proposed approach is subjectivity which consists in the choice of indicators for assessing economic security that form a particular area of economic security, determining the sufficiency of the number of factors, which accounts for the percentage of explained variance, and determining how many indicators are discarded based on the distribution of factor loading. Moreover, the analysis reveals the problem of mutual comparability of indicators for different periods, which prevents one from significantly increasing the sample. As a result of the study, the authors propose an approach to determining representative indicators based on the method of factor analysis. It is suggested to use the value of factor loading as the criterion for choosing a certain representative indicator. The authors also reveal how to consider the identified shortcomings of the proposed approach.

Keywords: Economic Security, Representative Indicators of Economic Security, Factor Analysis

RESUMO

O objetivo do estudo é adaptar o método de análise fatorial para a determinação de indicadores representativos. No artigo, é revelado o algoritmo para aplicação da análise fatorial de acordo com os objetivos de determinação de indicadores representativos. Os autores utilizam o método de análise fatorial e o método de componentes principais, por meio do qual é analisada uma amostra de sete indicadores de segurança econômica para o período de 2007 a 2020. A análise é realizada usando a plataforma de software de análise de dados IBM SPSS Statistics. Com base nos resultados da análise, conclui-se sobre a aplicabilidade do modelo fatorial, avaliam-se os fatores resultantes e propõe-se uma abordagem para a escolha de um indicador representativo com base na carga fatorial. A principal desvantagem da abordagem proposta é a subjetividade que consiste na escolha de indicadores para avaliar a segurança econômica que formam uma determinada área de segurança econômica, determinando a suficiência do número de fatores, que responde pelo percentual de variância explicada, e determinando como muitos indicadores são descartados com base na distribuição da carga fatorial. Além disso, a análise revela o problema da comparabilidade mútua de indicadores para diferentes períodos, o que impede que se aumente significativamente a amostra. Como resultado do estudo, os autores propõem uma abordagem para determinação de indicadores representativos com base no método de análise fatorial. Sugere-se utilizar o valor da carga fatorial como critério para escolha de um determinado indicador representativo. Os autores também revelam como considerar as deficiências identificadas da abordagem proposta.

Palavras-chave: Segurança Econômica, Indicadores Representativos de Segurança Econômica, Análise Fatorial

RESUMEN
El propósito del estudio es adaptar el método de análisis factorial para la determinación de indicadores representativos. Dentro del artículo, se revela el algoritmo para aplicar el análisis factorial de acuerdo con los objetivos de determinar indicadores representativos. Los autores utilizan el método de análisis factorial y el método de componentes principales, mediante los cuales se analiza una muestra de siete indicadores de seguridad económica para el período 2007-2020. El análisis se lleva a cabo utilizando la plataforma de software de análisis de datos IBM SPSS Statistics. Con base en los resultados del análisis, se llega a una conclusión sobre la aplicabilidad del modelo factorial, se evalúan los factores resultantes y se propone un enfoque para la elección de un indicador representativo basado en la carga factorial. La principal desventaja del enfoque propuesto es la subjetividad que consiste en la elección de indicadores para evaluar la seguridad económica que forman un área particular de seguridad económica, determinando la suficiencia del número de factores, que explica el porcentaje de varianza explicada, y determinando cómo muchos indicadores se descartan en función de la distribución de la carga factorial. Además, el análisis revela el problema de la comparabilidad mutua de indicadores para diferentes períodos, lo que impide aumentar significativamente la muestra. Como resultado del estudio, los autores proponen un enfoque para determinar indicadores representativos basado en el método de análisis factorial. Se sugiere utilizar el valor de la carga factorial como criterio para elegir un determinado indicador representativo. Los autores también revelan cómo considerar las deficiencias identificadas del enfoque propuesto.

Palabras clave: Seguridad Económica, Indicadores Representativos de La Seguridad Económica, Análisis Factorial

1. INTRODUCTION

In the current context of the globalized world, the role of economic sovereignty as an integral element of economic and national security is substantially increasing. The ability to influence the decisions of other participants in international economic relations creates new economic threats and increases the likelihood of their implementation. Consequently, the need to ensure economic security is growing. Economic security determines the long-term security of the state, the availability of funding sources and resources, the well-being of citizens, and the ability to meet basic human needs.

All this requires a timely, efficient and appropriate approach on the part of the state in the field of ensuring economic security. The adoption of timely and efficient measures by the subjects of ensuring economic security is a guarantee for the economy's resilience to crises and other urgent challenges and threats.

As in any management activity, an important stage in the work of the state to ensure economic security preceding the development of measures for ensuring economic security is the assessment stage.

We believe that one of the most crucial stages is the stage of diagnostics or assessment of the current situation, i.e. using information processing to establish if there are any deviations of the system from the equilibrium state. The notion of a system, in this case, is used as a set of interrelated elements of economic security, the change in the state of which under the influence of external and internal threats allows one to speak of a decrease or increase in the level of economic security (Larionov, Gureeva, 2019).

A timely realization of such a deviation is the basis for making the right management decisions and the foundation for further planning and forecasting the situation in the relevant area of economic security. In this regard, the study of assessment issues as a key element of the process of ensuring economic security is one of the most important tasks today.

At the same time, the economic security of the state is inseparable from the specific features of the national economy. In this regard, the criteria and indicators for assessing the economic security of one country may be different for another.

For example, for countries such as Italy, Spain, and Greece, indicators characterizing the size and structure of public debt reflect economic security better than for other countries whose economies are based on the export of energy resources, such as Saudi Arabia, Russia, and the UAE.

Within the framework of this article, only indicators characterizing the economic security of Russia are considered. Such indicators include the share of exports of high-tech goods in the volume of exports, the share of exports of fuel materials (mineral fuels, lubricants) in merchandise exports, the share of imports of high-tech goods in the volume of merchandise imports, the amount of public debt to GDP, the volume of gold and foreign exchange reserves, inflation, as well as the volume of broad money to GDP. These indicators form the foreign economic and financial spheres of Russia's economic security and reflect the threats to economic security associated with the low diversification of the national economy and high dependence on imports of high-tech goods, as well as financial instability.

To obtain the most complete results of assessing economic security, as a rule, more indicators are required. Moreover, the indicators used in the assessment are often chaotic, not structured, which complicates this process (Krivorotov et al., 2015).

Furthermore, not all indicators that are included in the assessment form the basis of a final opinion on the level of economic security.

Given this, it is extremely important to study approaches to the classification of economic security indicators and the selection of the most representative of them. We believe that representativeness is such a property of an individual indicator or a sample of indicators that allows one to get an idea of the whole from its elements.

As for the assessment of economic security, the representativeness of the indicators allows the use of their optimal number in the assessment. Optimality is determined by the preservation of information as a result of assessing these representative indicators. The information should be sufficient for drawing conclusions and making appropriate decisions by the subjects of ensuring economic security.

Moreover, the use of the entire array of indicators in the assessment is irrational because, with a significant increase in the number of indicators involved in the assessment, the indicators cease to affect the accuracy of calculations (Kornilov, Yushin, 2019). Given this, the purpose of the study is to adapt statistical methods to determining representative indicators of economic security. As such methods, we used the method of factor analysis, which is a procedure for combining the variables that are closest to each other into factors or components, and the method of principal components, which reduces data dimension with minimal loss of useful information.

2 METHODS

To achieve the goal of the research, we used quantitative research methods, in particular, factor analysis and the method of principal components.

The application of the method of principal components for the selection of representative indicators of economic security reduced the number of variables based on correlations between indicators while preserving essential information. The use of the factor analysis method made it possible to identify those indicators that have the greatest contribution to the formation of a particular factor (Zeynivandnezhad, Rashed, Kanooni, 2019; Aivazyan et al., 1989; Fomina, 2017).

Factor analysis and the method of principal components in this article were used exclusively to identify the indicator with the highest factor loading, interpreted as a representative indicator, and the combination of indicators into factors, which traditionally takes place in factor analysis, was not planned in this study.

The selection of representative indicators consisted of the following stages.

At the first stage, we formed a sample of seven indicators for the period from 2007 to 2020.

At the second stage, we analyzed the quality of the factorial model.

Based on the Kaiser-Meyer-Olkin measure of sampling adequacy, the hypothesis about the identity of the matrix of correlations of the initial features was estimated, if the value was more than 0.5 and the p-value (vl.) was less than the significance level of 0.05, then, according to Bartlett's test, the hypothesis that the correlation matrix of the original features is an identity matrix was rejected, and such a model was considered applicable (Yong, Pearce, 2013).

At the third stage, after analyzing the quality of the model using the method of principal components, the number of significant factors and their share of the explained variance were determined. The percentage or proportion of the explained variance is the explanatory value of a component which reflects how much a change in a factor or component is caused by a change in the indicators that form it.

After determining the number of factors, the structure of factors and the contribution of each indicator to their formation were analyzed.

At the fourth stage, using the factor analysis method, we studied the structure of factors identified using the method of principal components and calculated the factor loading of each indicator in the factor structure. The indicator with the highest factor loading was interpreted as a representative indicator.

Factor loading reflects the relationship between the indicator and the factor, is a special counterpart of the correlation coefficient, which also varies from -1 to 1 (Watkins, 2018). The closer the relationship of this feature with the factor under consideration, the higher the value of the factor loading. The positive value of the factor loading indicates a direct (and the negative value – the indirect) relationship of this feature with the factor (Dvoeryadkina, Chalkina, 2011).

The described statistical data analysis was carried out using a special software package for data analysis IBM SPSS Statistics.

3. RESULTS

Within the framework of the suggested approach to choosing representative indicators of economic security, it is proposed to consider indicators of the foreign economic and financial spheres.

At the first stage of the selection of representative indicators, a sample is formed for factor analysis separately for each area of economic security.

The *foreign economic sphere of economic security* includes the following indicators: the share of exports of high-tech goods in the volume of exports, the share of exports of fuel materials (mineral fuels, lubricants) in commodity exports, the share of imports of high-tech goods in the volume of merchandise imports.

The financial sphere of economic security is reflected by such indicators as the size of public debt to GDP, the volume of foreign exchange reserves, inflation, the volume of broad money to GDP.

Naturally, the set of indicators presented for each considered area of economic security is not exhaustive. The choice of these indicators is due to the availability of relevant information in statistical databases.

The proposed approach to the selection of representative indicators for the set of indicators is implemented solely to describe its applicability.

Taking this into account, the data from 2007 to 2020 are presented for each of these indicators (Table 1). The source of information for this was the data of the World Bank.

Table 1
Indicators that characterize the foreign political and economic spheres of economic security

Year	Share of high-technology exports in manufactured export volume (High-technology exports, 2021), %	Share of fuel exports (mineral fuels, lubricants) in merchandize exports (Fuel exports, 2021), %	Share of ICT goods imports in goods import volume (ICT goods imports, 2021), %	Central government debt to GDP (Central government debt, total, 2021), %	Gold and foreign exchange reserves (Total reserves, 2021), USD billion	Inflation (Inflation, consumer prices, 2021), %	Broad money to GDP (Broad money, 2021), %
2007	7.24	61.46	8.60	7.20	478,822,286,132	9.01	42.98

2008	7.03	65.68	7.79	6.50	426,278,773,722	14.11	39.51
2009	9.72	63.01	7.28	8.30	439,341,754,765	11.65	49.30
2010	9.56	65.65	8.53	9.00	479,222,324,221	6.85	51.44
2011	8.51	67.03	7.16	9.50	497,410,212,789	8.44	47.39
2012	9.16	70.29	7.50	10.50	537,816,372,807	5.07	47.29
2013	10.73	70.56	6.84	11.30	509,692,074,389	6.75	51.20
2014	12.18	69.53	7.88	14.40	386,216,337,149	7.82	54.30
2015	16.08	62.84	9.14	13.60	368,042,950,259	15.53	61.83
2016	15.86	48.29	8.40	12.90	377,052,204,308	7.04	59.45
2017	12.44	49.12	8.67	13.50	432,730,507,964	3.68	59.52
2018	11.44	52.68	9.91	14.50	468,645,216,083	2.88	59.12
2019	13.00	51.95	9.36	14.60	555,179,461,639	4.47	59.08
2020	15.02	60.71	9.73	17.80	596,769,862,770	3.38	70.38

Source: Author

After the sample for factor analysis is formed, the second stage of selecting representative indicators is carried out - the quality of the factor model is analyzed.

Samples of indicators are close to normal distribution.

Table 2
KMO and Bartlett's test for indicators of foreign economic and financial spheres of economic security

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)		0.597
Bartlett's test	Approximate value of Chi-squared	72.984
	Degrees of freedom	21
	Significance	0.000

Source: Author

At the third stage of the selection of representative indicators, the quality of the resulting factor model is analyzed.

According to the value of the KMO measure, which is more than 0.5 (0.597), and the Bartlett test, the correlation matrix is not an identity one, and the factor model is applicable (Table 2).

At the third stage of the selection of representative indicators, the principal component method determines the number of factors.

Table 3
The explained cumulative variance of indicators in the foreign economic and financial spheres of economic security

Compone nt	Initial eigenvalues			Sum of squared loadings			Rotation of sum of squared loadings		
	Total	% of variance	Total %	Total	% of variance	Total %	Total	% of variance	Total %
1	3.917	55.950	55.950	3.917	55.950	55.950	3.722	53.167	53.167
2	1.529	21.848	77.798	1.529	21.848	77.798	1.724	24.631	77.798
3	0.816	11.662	89.460						
4	0.456	6.512	95.972						
5	0.208	2.973	98.945						
6	0.046	0.650	99.595						
7	0.028	0.405	100.000						
Factor identification method: principal component method.									

Source: Author

As one can see from Table 3, during the analysis of seven indicators, it was proposed to focus on two factors or components that account for the largest percentage of the explained variance, namely 77.8%. In other words, a change in two factors can explain the change in all indicators by 77.8%.
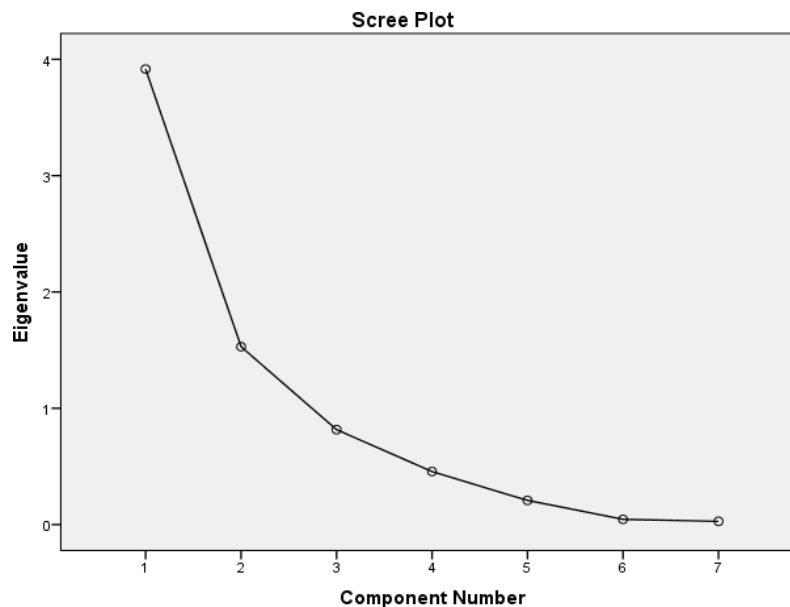

Fig. 1. Eigenvalue plot

The selection of factors can be represented in the form of a "scree" graph in Fig. 1, which shows that, according to the Kaiser criterion, only two factors or components have eigenvalues greater than one. In this regard, two factors should be retained. To determine the composition of factors, let us consider their structure in greater detail.

Table 4
The structure of factors

Indicators	Component	
	1	2
Share of high-technology exports in manufactured export volume, %	0.919	-0.141
Share of fuel exports (mineral fuels, lubricants) in merchandise exports, %	-0.708	0.001
Share of ICT goods imports in goods import volume, %	0.770	0.190
Gold and foreign exchange reserves, USD billion	-0.107	0.930
Inflation	-0.356	-0.822
Broad money to GDP, %	0.939	0.192
Central government debt to GDP, %	0.874	0.302

Source: Author

At the last, fourth stage of the selection of representative indicators with the help of factor analysis, the structure of factors is studied and indicators with the highest factor load are determined. On this basis, a representative indicator of economic security is selected.

For the greatest reliability, those indicators are selected whose coefficients exceed 0.8. In this case, the first component or factor is formed by the indicator of the share of high-tech exports in the volume of exports, the volume of broad money to GDP, and the size of central government debt to GDP. The second component is formed by the volume of gold and foreign exchange reserves and inflation, respectively.

The resulting structure of the first component does not allow one to unambiguously define it as a factor characterizing the foreign economic sphere of economic security. This is due to the fact that two of the three indicators (the volume of broad money to GDP, the size of central government debt to GDP) of the first component, in terms of their content, characterize the financial sphere rather than the foreign economic sphere. Based on the structure of the second component, it can be defined as a factor in the financial sphere of economic security. To identify a representative indicator within the framework of this factor, it is necessary to consider the distribution of factor loadings, which show which variables load the factor the most. The higher the loading value, the more the indicator correlates with the

factor, and the more the variable is determined by this factor. Thus, the indicator "volume of gold and foreign exchange reserves" has the highest factor load, amounts to 0.930 (Table 4), which allows one to define it as representative and in the future, when considering the financial sphere of economic security, focus on the changes to this indicator.

The communality indicator is interesting from the point of view of determining the representativeness of indicators using the method of factor analysis. Communality is the part of the variance of a variable explained by principal components or factors. In other words, this indicator reflects the total loading of one indicator in all selected factors. Thus, communality allows one to determine the indicator that explains the change in all factors.

Table 5
Factor communality

Indicator	Total factor loading of the indicator
Share of high-technology exports in manufactured export volume, %	0.810
Share of fuel exports (mineral fuels, lubricants) in merchandise exports, %	0.602
Share of ICT goods imports in goods import volume, %	0.686
Gold and foreign exchange reserves, USD billion	0.873
Inflation	0.806
Broad money to GDP, %	0.861

Source: Author

The indicator "the volume of gold and foreign exchange reserves" has the greatest aggregate factor loading among the analyzed indicators, which amounts to 0.873 (Table 5).

Thus, we can conclude that based on the analysis of factor loadings, both within the selected components or factors, and by analyzing the aggregate factor loadings, the indicator "volume of gold and foreign exchange reserves" is a representative indicator of economic security.

2. DISCUSSION

The approach to determining representative indicators presented in the article is not devoid of some shortcomings, in particular, subjectivity in the formation of a sample of indicators and the choice of the most representative indicator, therefore, the approach can be applied to a certain degree of convention.

First, one should note the influence of subjectivity on factor analysis. The problem of determining the number of factors that must be preserved based on the results of factor analysis is under debate in the scientific community (Auerswald, Moshagen, 2019). The

quality of the factor model depends on the preservation of a certain number of factors. Thus, as a result of the analysis of seven indicators carried out in the article, the total share of the explained variance of the two factors amounted to 77.8%. However, according to some scientists, the value of the cumulative variance below 85% does not allow one to consider the obtained factors sufficiently informative (Yang et al., 2002). On the one hand, one cannot but agree that the aggregate variance should be as high as possible. In this case, the choice of the sufficiency of the proportion of the explained variance, as well as the set of indicators to be analyzed, ultimately remains with the researcher. For example, within the framework of this article, the obtained indicator "volume of gold and foreign exchange reserves" is representative only due to the small number of indicators in the sample. With a significant increase in the sample, the probability of this indicator becoming representative will be much lower.

Moreover, in the structure of the second factor, both the volume of gold and foreign exchange reserves and inflation have a sufficiently large contribution (more than 0.8) to the factor, while the choice of only one indicator as a representative one, and not all indicators satisfying the threshold value equal to 0.8, reduces the explanatory or informative role of the remaining indicator. Thus, according to Watkins (2018), the number of indicators that form the factor should be at least three, although it is preferable to use more indicators. Another controversial issue is the size of the factor loading of the indicator sufficient to include it in the factor. Often, the size of the factor loading of 0.7 and higher is considered sufficient (Ul Hadia et al., 2016). However, within the framework of this article, for greater certainty, it is proposed to focus on the value of 0.8.

Therefore, the subjectivity of factor analysis manifests itself at the stage of forming a sample of indicators, as well as at the stage of determining the sufficiency of certain factors. Subjectivity in determining the representativeness of a particular indicator is based on the need to select a limited number of indicators in the structure of a factor as representative. Second, a significant obstacle in the formation of a sample for analysis is the problem of comparability of indicators with each other due to the lack of data for certain periods. This problem requires either replacing part of the indicators with those for which information is present in statistical databases sufficient for analysis, or searching for data on indicators in other sources. The solution to this problem is presented in the article by Y. Samusevych, A.

Vysochyna, T. Vasylieva, S. Lyenov, and S. Pokhylko (2021), where the authors use the indicators for factor analysis, information on which is available in sufficient quantity in one statistical database. Moreover, filling in the missing information on the same indicator based on different sources is undesirable, because different statistical agencies use different calculation methods, which can ultimately adversely affect the results of the analysis.

5. CONCLUSIONS

The described approach to the selection of representative indicators based on the factor analysis method revealed the following:

- the role of the subjective factor in the choice of a representative indicator using statistical methods is less essential than for the method of expert assessments, but still significant. Thus, subjectivity is manifested at the stage of forming the sample subject to factor analysis, as well as at the stage of determining how many factors and forming indicators to leave;

- to increase the reliability of the analysis results, the sample should be formed based on a lot of indicators homogeneous in their content, i.e., strive to ensure that all of them, as much as possible, characterize the same area as fully as possible;

- the choice of representative indicators should, if possible, be based on several indicators with the maximum factor loading rather than one. This will help preserve more information.

The indicators of economic security reviewed in this article were selected based on the sufficiency of statistical information on them and solely to demonstrate the application of the presented approach.

The practical use of such an approach to select representative indicators should help to reduce the complexity of calculations and increase the reliability of the results of further assessment.

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