Assessment the development of the commodity structure a country's exports and imports (case study of Ukraine)

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ABSTRACT

The article discusses the solution of the problem of splitting the mixture in order to solve the problem of estimating the development of the commodity structure of exports and imports of the country, using the example of quarterly values of economic indicators of Ukraine during 2016 - 2020 g.g. Analysis of the scientists work involved in the solution of the mixture separation shows that there are many approaches and methods. Most of these methods provide a classical approach, supported by Pearson K., which proposed an asymmetric distribution of values to represent a mixture of two normal laws, while applying the moment method to determine the parameters of individual distributions. In modern conditions, there are other methods of mixing separation, such as EM algorithms, cluster analysis methods. The practical application of Ward's method in cluster analysis to determine the structure of the population of objects in the economy and its mathematical content is evidenced by his recommendation for the separation of the mixture. Measuring the evolution of the product structure of exports and imports is always a challenge for all countries of the world. In the asymmetric distribution of economic indicators, it is useful to distinguish two distributions by cluster analysis using the Ward's method. At the same time, to characterize these distributions use well-established estimates, namely median and interquartile range, divided by 1,35. This allows us to establish a trend of growth or decline.

INTRODUCTION

Today, the world economy is undergoing intensive changes and it characterized by the development of new processes and phenomena. The last year of global economic turmoil was associated with quarantine measures to spread COVID. However, many analysts believe that in 2021 the EU will enter a

new phase of development with measures such as the creation of a recovery fund, while the harmonization of climate targets and the development of a common vaccination strategy are all prerequisites for closer community cooperation. The economic development of a country is influenced by the commodity structure of exports and imports, which reflects the specialization of the country, its foreign economic opportunities, and guides economic policy (Pejanovic, 2020, p. 77).

In order to understand the new processes in the economy, it is important to assess the state of their development, which is connected with the search for methods for determining the initial stages of changes and structural changes (Kolodiziev et al., 2018). To detect these transformations in economics, mathematicians recommend several methods, one of which is the method of separation the mixture. The task of splitting a mixture has always been a difficult mathematical problem. Multi-dimensional analysis of large statistical data sets in an economy is mostly based on the hypothesis of their normal distribution, which is often not performed. Almost any deviation from the normal distribution can be explained by the fact that the sample, the population, is not homogeneous, but consists of several normally distributed sub-populations.

1. LITERATURE REVIEW

According to the analysis of the evolution the commodity structure of a country's exports and imports, economists in theory and practice always address this problem in detail. Although a great deal of work has been done to study and solve this problem, it is worth highlighting such work. A detailed analysis of the structure of foreign trade was carried out by Helpman E. (1999). In the conclusions, the author draws attention to the need for a more technologically oriented trade theory and a greater focus on dynamics in order to understand the processes that are taking place. O. Lozanov and S. Zhivkova (2017) in their work identifies the positive and negative results of export development in Bulgaria before and after EU accession and has justified specific recommendations to change the product structure of exports in order to improve the competitiveness of the Bulgarian economy. G. Idrisov G., et al. (2016) clearly demonstrate how structural changes aimed at diversifying production and exports affect the sustainability of economic development, social stability of the country. With the help of mathematical tools, Li et al. (2020) investigated the structure of China's trade and obtained valuable economic conclusions on further promoting Eurasian economic and trade integration. An in-depth analysis of the structural changes in foreign trade of the Eurasian Union is given in the work of I.S. Gladkov et al. (2018), and the main parameters of the evolution and structure of the EU foreign trade during the period of transformation of international trade and economic relations have been identified. M. Baxter and M. Kouparitsas (2003) in their work gave the results of investigations of the commodity structure of exports and imports of the country and compared with the commodity structure of its trading partner. The conclusions of these authors on the relation of dispersion in exports and imports with factor endowment of partners are interesting. It should be noted that scholars and practitioners have paid much attention to the evolution of some elements of a country's merchandise composition of exports and imports over time, but little research has been done on the evolution of this structure as a whole.

2. DATA AND METHODOLOGY

In order to separate the mixture, we suggest the use of cluster analysis in the first stage, which will allow the number of components and their composition to be determined from the mixture data. The basis of this proposal is the fact that the cluster analysis has made significant progress over the last decades and that some modern forms of analysis are credible for the integrity of the classification (this was sufficiently stated in the previous section). One of such reliable procedures we consider the Ward's method (Ponomarenko and Malyarets, 2009). This method uses dispersion analysis methods and assumes that the two clusters will be closest if they are combined to minimize the increase in total dispersion. The target function is represented as the average group sum of squares or the sum of squares of deviations (σ^2) calculated by the formula:

$$\sigma^2 = x_j^2 - \frac{\left(\sum_j x_j\right)^2}{n},$$ where x_j - the value of a feature of the same j-object.

First, when each cluster consists of one object, $\sigma^2 = 0$. The Ward's method combines those groups or objects for which σ^2 is obtained minimum increment. The method involves finding clusters of almost equal size that have a hyperspherical shape. It is recommended to apply this method to problems with near-located clusters. The distance between objects in the Ward's method is assumed to be medium Euclidean.

2.1 Application of the Model

To ensure the sustainability of the country's development, it is important to analyse the commodity structure of exports and imports. Consider the problem solution of splitting the mixture using the Ward's method of cluster analysis to solve the problem of determining the development elements of the commodity structure exports and imports of the country, using the example of quarterly data of Ukraine during 2016-2020 (*Official site of the National Bank of Ukraine*). We shall mark the elements of the product structure of Ukraine's exports: x_1 - Food products and raw materials for their production; x_2 - Mineral products; x_3 - Chemical and related industries; x_4 - Timber and products thereof; x_5 - Industrial products; x_6 - Ferrous and non-ferrous metals and products; x_7 - Machinery, equipment, vehicles and appliances; x_8 - other. We shall also mark the elements of the product structure of Ukraine's imports: z_1 - Food products and raw materials for their production; z_2 - Mineral products; z_3 - Chemical and related industries; z_4 - Timber and products thereof; z_5 - Industrial products; z_6 - Ferrous and non-ferrous metals and products; z_7 - Machinery, equipment, vehicles and appliances; z_8 - other.

First, to assess the development of the commodity structure of Ukraine's exports during 2016-2020 quarterly based on the solution of the mixture distribution problem, density trace should be constructed for (Figure 1).
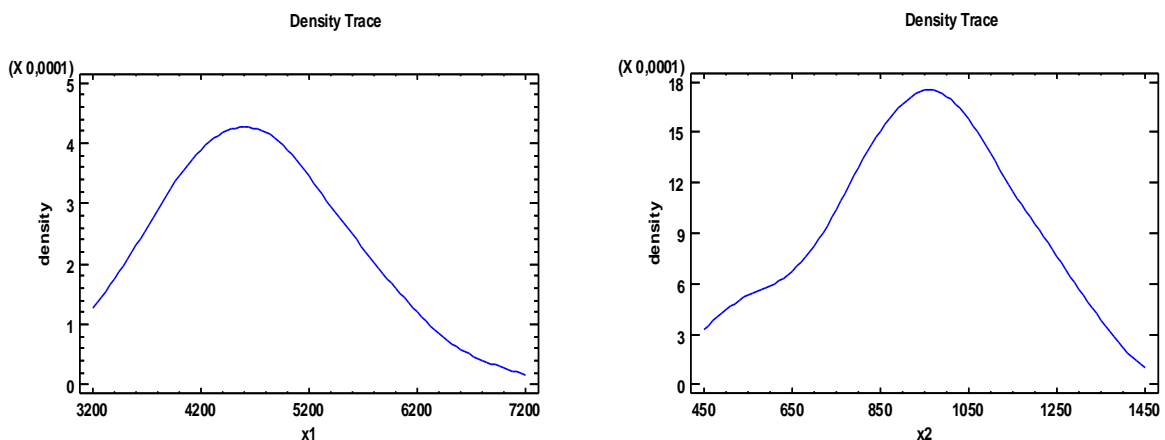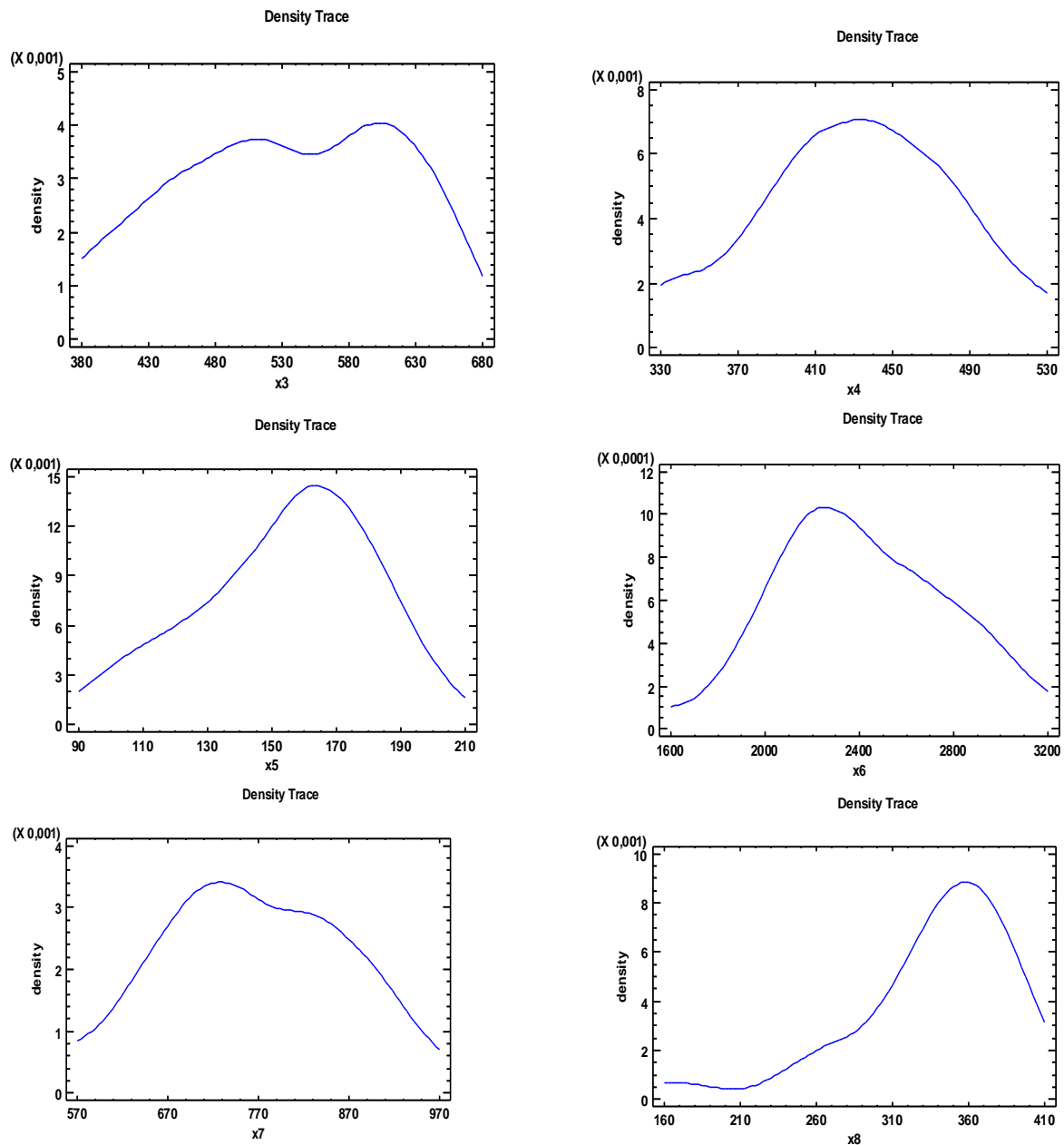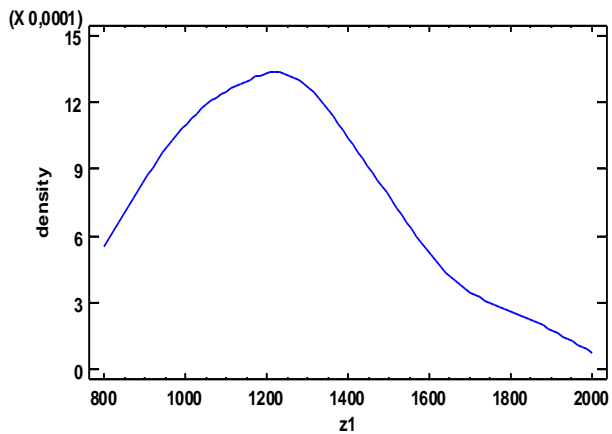
Figure 1. Density trace elements of Ukraine's export structure during 2016 - 2020 quarterly
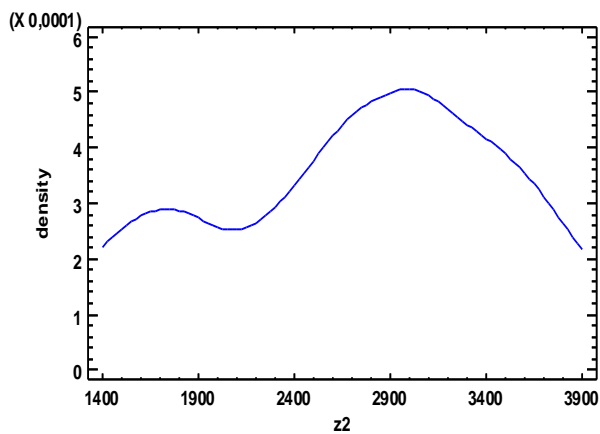
Source: own research.

From the point of view of trace density, it is useful to draw conclusions about the homogeneity of the values of the elements of the product structure of exports and imports of a country. If the curves of the type coincide with the function of the distribution of the normal law, then the sum of the values of the corresponding indicator can be considered homogeneous, otherwise heterogeneous, and the population should be investigated in detail.

Thus, changes in values of chemical and related industries (x_3), machinery, equipment, vehicles and devices (x_7), other (x_8) product structure of exports show heterogeneity, and each consists of several normally distributed sub-components. Similarly, density trace was built for the commodity structure of Ukraine's exports during 2016-2020 quarterly (Figure 2).
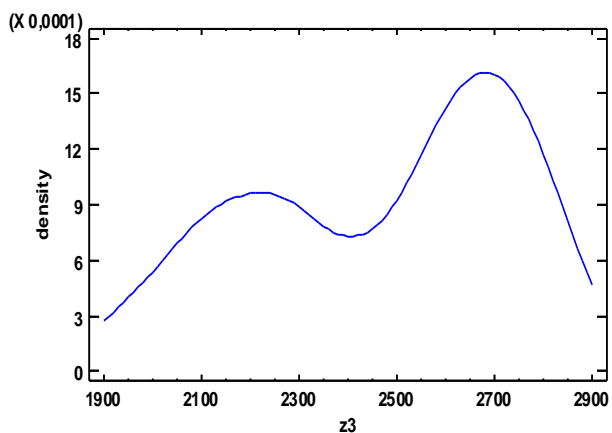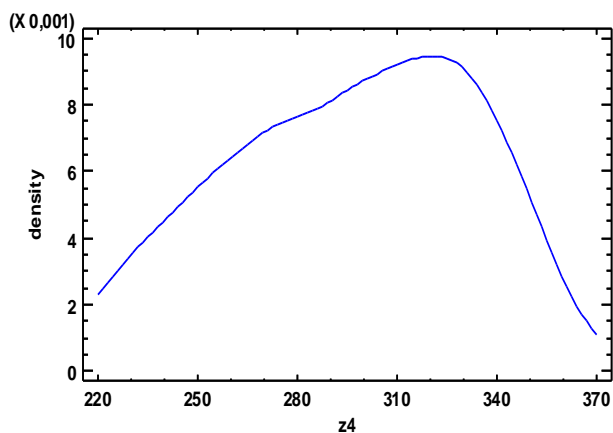
Density Trace

(X 0,0001)
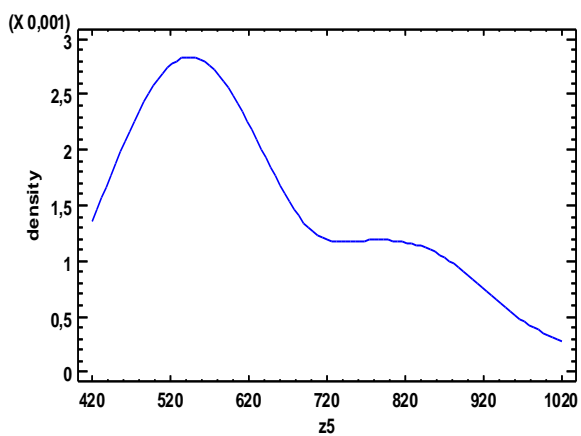
density

z1

Density Trace

(X 0,0001)

density

z2

Density Trace

(X 0,0001)

density

z3

Density Trace

(X 0,001)

density

z4

Density Trace

(X 0,001)

density

z5

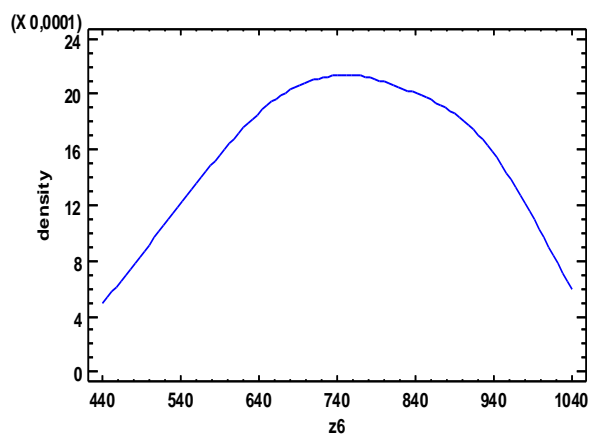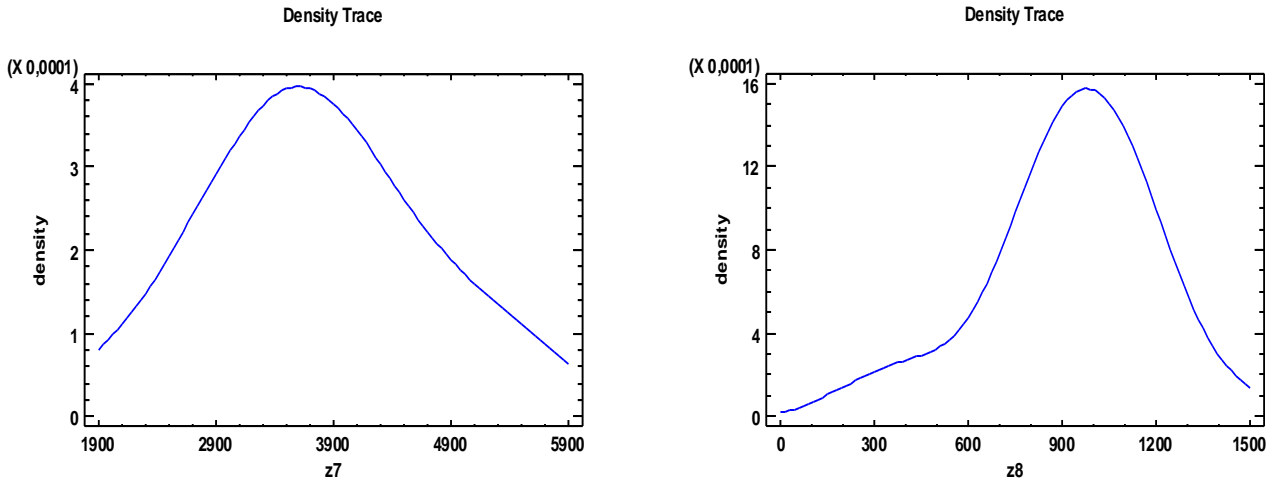Density Trace

(X 0,0001)

density

z6

Figure 2. Density trace elements of Ukraine's import structure during 2016 - 2020 quarterly

Source: own research.

The tracetracedensity curve of the import structure of Ukraine also shows the heterogeneity of the values of the constituents, is mineral products (z_2), products of chemical and related industries (z_3), wood and products thereof (z_4), industrial products (z_5).Thus, in order to separate the heterogeneous aggregates of certain components of the commodity structure of exports and imports of a country, it is recommended to use cluster analysis to derive the number and composition of homogeneous subsets. Figure 3 shows the results of the Ward's procedure as a dendrogram. In Figure 3 (a), are witnessing two main classes for for x_3. In the dendrogram in Figure 3 (b) it is taken into account that clusters 2 and instead of object numbers on the horizontal axis are the values of the indicator x_3 (there is one sign).

a)   b)
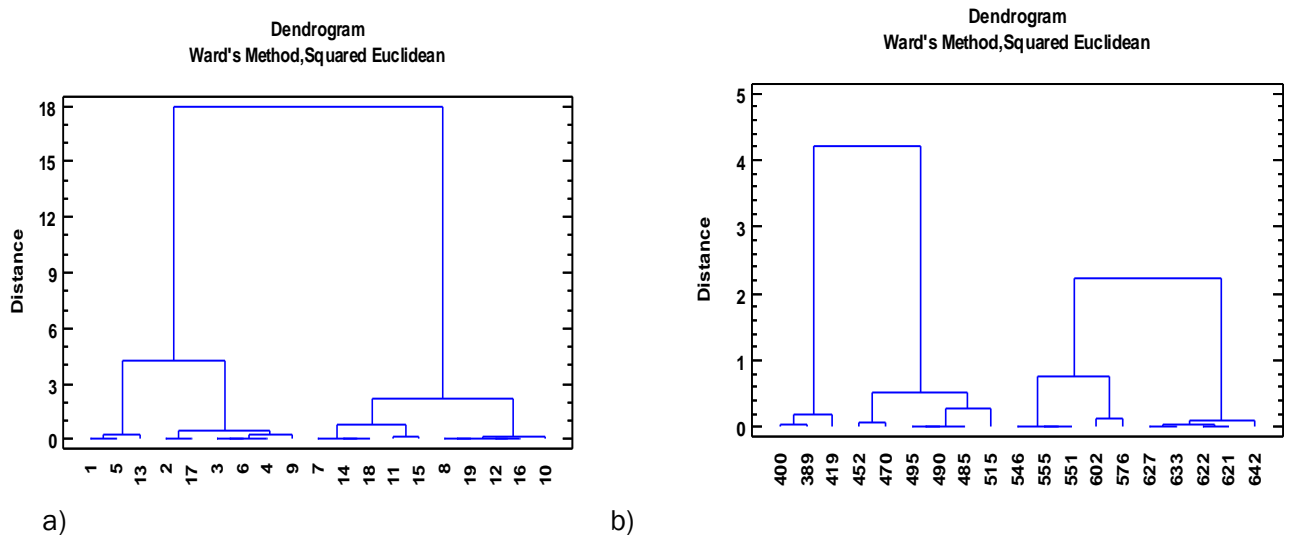
Figure 3. Dendrogram stratification (chemical and related industries)

Source: own research.

This shows that the value of the feature is in the first group $x_3 \leq 546$ and in the second group - $x_3 \geq 546$. The numerical characteristics of both clusters were also calculated using the Statgraphics package. In Table 1 the statistical characteristics of the two samples are presented.

Table 1. Characteristics of the two clusters (samples) for (chemical and related industries).

Characteristics	1st cluster	2nd cluster
Count	9	10
Average	457,222	597,5
Median	470	611,5
Variance	2023,94	1374,06
Standard deviation	44,9883	37,0683
Standard error	14,9961	11,722
Minimum	389	546
Maximum	515	642
Range	126	96
Lower quartile	419	555
Upper quartile	490	627
Interquartile range	71	72
1/6 sextile	400	551
5/6 sextile	495	633

The content of Table 1 confirms in values the existence of two under totals chemical and related industries (x_3). By comparing the numerical characteristics of the two under the combinations of chemical and related industries, there are two different distributions of values.

Figure 4. Shows a graphical variation of values between the two samples, showing radical differences.
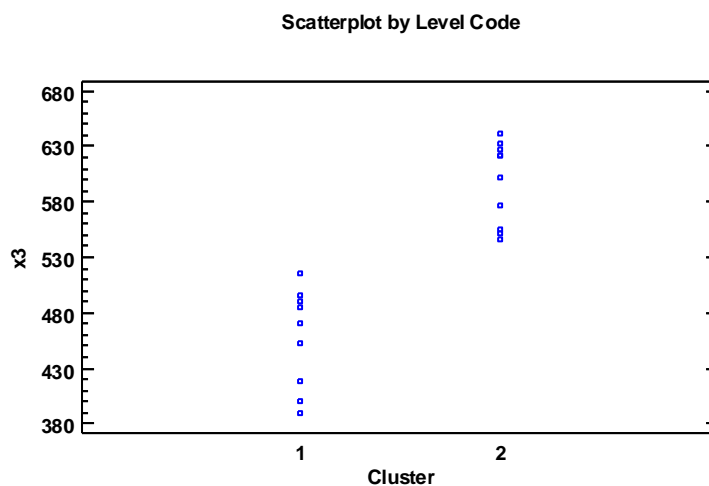

Figure 4. Graph of variation of topic values between two samples

Source: own research.

A block diagram provides a visual representation of the distribution. It does not contain any small detail and allows the whole picture to be covered, and it also allows comparisons of several under the totals without entering into the smallest details of each. As is well known, the block diagram contains five basic characteristics of a one-dimensional dataset and allows for a rapid determination of the distribution.

Figure 5. shows a block diagram containing five basic characteristics of a one-dimensional set of attributes for each sample.
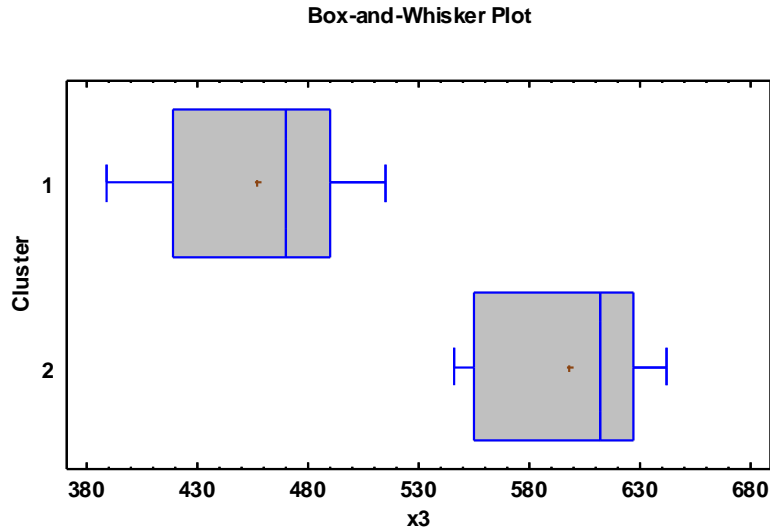

Figure 5. Single-dimensional data set block diagram for each of the two samples

Source: own research.

On the same scale, block diagrams of the volume of chemical products and related industries exported on Figure 5 confirm the differences between the two data sets, which are combined in one population.

2. FURTHER CONSIDERATIONS AND DISCUSSION

The second step of the proposed procedure is to define the parameters of the two subscriptions. C Tabular. 1 should $p_1 = \dfrac{9}{19} = 0{,}474$ and $p_2 = \dfrac{10}{19} = 0{,}526$. We consider that sample mean and mean square deviations are biased estimates for the relevant parameters. Well-established estimates for large deviations (or emissions) of observations are the median (as an estimate of the centre of distribution $Me_1 = 470, Me_2 = 611{,}5$) and the interquartile range (IQR) for the estimation of variability (IQR1 = 71 and IQR2 = 72). In the interval between the top quartile and the bottom quartile, 50% of the observations are made; in the normal law, the width of this interval is $1{,}35\sigma$ equal to that of the fixed estimates

$$\sigma_1 = \frac{71}{1{,}35} = 52{,}593 \; ; \; \sigma_2 = \frac{72}{1{,}35} = 53{,}333 \, .$$

Table 2 shows the established characteristics for each subset of the values of the components of the structure of exports, which are x_3 (chemical and related industries), x_7 (machinery, equipment, vehicles and appliances), x_8 (other) and the components of the commodity structure of imports are z_2

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(mineral products), z_3 (chemical and related industries), z_4 (wood and wood products), z_5 (industrial products).

Table 2. Well-established characteristics of sub-branches of heterogeneous values of the components of the commodity structure of exports and imports of Ukraine (2016 - 2020, quarters)

Component of the product structure	Median Me		Standard deviation σ		Development trend
Export					
chemical and related industries	470	611,5	52,593	53,333	Growth
Machinery, equipment, vehicles and apparatus	683,0	827,0	78,519	99,259	Growth
other	356,0	267,0	24,44	88,889	Decrease
Import					
mineral products	3409,0	2209,0	480,74	863,704	Decrease
chemical and related industries	2214,0	2683,0	222,222	115,556	Growth
wood and wood products	276,0	327,0	44,444	18,519	Growth
industrial products	545,5	850,0	114,815	140	Growth

Source: own research.

The content of Table 2 shows that changes in the structure of Ukraine's foreign trade took place during the period under study. Given the chaotic nature of Ukraine's foreign trade, its heavy dependence on a changing external environment and the political situation in the country, it is first and foremost necessary to review the commodity structure of exports and imports and to determine the direction of further development. Table 2 provides further economic analysis of qualitative changes in the composition of a country's merchandise exports and imports.

CONCLUSIONS

The prospects for the development of each country's foreign trade today depend on its success in adapting to the conditions of international economic relations and are gradually being transformed. In the current circumstances, international events have shown that, owing to the clash of geo-economic and geopolitical interests of a number of powerful players in the world economy, certain changes in the international trading system as a whole are likely. It is therefore important to determine the status and processes of maintaining or changing trends in a country's foreign trade. In sum, there is merit in using the task of sharing the mixture to solve the problem of defining the stages of a country's foreign trade development process, namely, to determine when a new stage of development is emerging, A new stage in the development of the one-dimensional process and its level of progressivity.

Thus, it is advisable to use this task in solving the problem of defining the stages of the development process of objects in the economy, namely, the moment when a new stage of development is born, a new stage of development of a one-dimensional process and its level of progression. Thus, the analysis of changes in the commodity structure of Ukraine's exports and imports (2016-2020, quarters) shows different quality of their development (progress or regression), which requires further economic analysis, but it is useful to diagnose the onset of these changes and the magnitude by solving the problem of splitting the mixture using a cluster method based on the Ward's method.

The application of cluster analysis simply determines the number of components (there may be more than two), their composition and the characteristics of the well-distributed sub-components, and this is a well-established decision on the availability of emissions.

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