Modelling of trade relations between EU countries by the method of minimum spanning trees using different measures of similarity

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Abstract. The article is devoted to the study of changes in relations between the countries of the European Union based on modeling and analysis of the structure of trade relations between countries. The article analyzes the dynamics of exports and imports of goods and services between the countries of the European Union on the basis of data taken for the period from 2006 to 2019. The study is based on one of the methods of cluster analysis, namely – the method of constructing minimal spanning trees. For the analysis the method of visualization of links is defined and the choice of the corresponding graphic representation is substantiated: the display of links using the dendrograms which carry more information in comparison with display of the minimum spanning trees in the form of a planar graph is chosen. Four different methods were used to construct the minimum spanning trees on the basis of which the visualization of links is performed: the Single link method, the averaged link method, the complete links method, and the Ward method. Based on the analysis of the results obtained using each of the methods, the best of them is selected, which is then used throughout the study. As a result of the study, suggests were made about the criteria by which clusters are formed within the European market. Such criteria are both the geographical neighborhood, which means mostly similar climatic conditions, and the common strategy of economic development of the country and the common strategy of behavior in the world market. In addition, a number of countries have been identified that are gradually moving to the use of their own economic strategies, as well as a number of countries seeking to align strategies of behavior in the world market. The influence of such factors as joining the integration union of new member states and global financial crises on the structure of trade relations is substantiated. Changes in the structure of relations between EU countries due to the influence of these factors are simulated. The study is of an applied nature and can be used in the future as a methodological basis for developing effective mechanisms for reformatting trade relations between countries in the context of geoeconomic transformations and global financial crises.

Keywords: cluster analysis, minimum spanning tree, cluster, dendrogram, European Union, international trade, import, export.

1 Introduction

International trade is one of the oldest and most important forms of implementation of the international division of labour and world economic relations. At the same time, it is the traditional and most developed form of international economic relations.

International trade has grown markedly over the past two centuries [13]. Today, about a quarter of the world's production is exported. This has had a significant impact on the geo-economic structure of the world economy, with the emergence of new centres of economic power and the formation of regional integration associations and coalitions.

The integration of national economies into the world economic system was one of the most important events of the last century. The development and deepening of international trade links have played a role in the formation of integration groupings. At the same time, the processes of integration, in the present circumstances, are conducive to a significant increase in the volume of exports and imports of goods and services between countries. This is particularly true for regional association of countries. Among these, the European Union plays a special role. It is within this integration framework that trade relations have reached the highest stage of their development. At the same time, contemporary threats and challenges have a significant impact on the stability of such links. New members, not always with a high level of economic development, are periodically joining. Or, like the United Kingdom, leaving it [8]. Global financial crises and other external and internal factors also destabilize the situation.

In this context, studies aimed at identifying structural changes in the reformatting of trade relations between countries and the reasons for such changes are of particular importance. One of the modern methods of economic and mathematical modelling that works effectively in such research subjects is cluster analysis and its specific tools: graph theory and minimum spanning tree construction techniques. This article deals with the modelling of trade links between EU countries using spanning tree methods.

2 Literature review

The analysis of the scientific work shows that the researchers possess many developed methods of the modelling trade processes between countries. They target individual countries, integration associations, certain groups of goods and services, etc.

In [9] regression models were used to link trade flows and gross products of all

BRICs countries. The authors have developed a theoretical model that allows us to obtain endogenous macroeconomic models taking into account bilateral trade between all BRIC countries and foreign trade with the rest of the world. The Dixit-Stiglitz model was used to study the effects of international trade [20].

In a study of the dynamics and forecasting of international trade, a gravity model is widely available. For example, [11] tests and compares classical and gravitational trade models with the example of the United Kingdom, with the authors noting the best applicability of the classical model to the United Kingdom.

The study of the impact on international seafood trade of factors such as geographical distance between countries, trade agreements, gross product and other macroeconomic variables using the gravity model is presented in [12].

The extended Frankel gravity model was used by authors [3] in a study of India's bilateral external trade relations with ASEAN countries.

The authors [2] based on the gravity model, consider trade flows between China and its major global partners.

The international trade factor model in the euro area, based on the identification of the interaction between macroeconomic and trade substitutes, is proposed in [5] and proved to be effective for short-term forecasts.

There have recently been publications using network theory to the modelling international trade processes. Thus, the authors [15] consider international trade as a multi-level network.

In such studies, various econophysical methods are used to analyze complex economic systems. For example, in recent years, an analysis of the cryptocurrency market has been conducted using similar methods [18; 19], some of which also underlie the mathematical methods used in this work.

In summary, the above analysis of a sample of contemporary publications proves the relevance of the topic and the interest of scientists in the further development and application of new approaches to the modelling trade links between countries within integration association or globally. The aim of this research is to present the results of the modelling trade links between the countries of the European Union using the minimum spanning tree method and to analyses the changes in the structure of these links as a result of the impact of different social and economic, political factors.

3 Method and materials

It is proposed to assess trade links between countries and their evolution over time using the approach described by Rosario N. Mantegna [10]. This approach is based on constructing a minimum spanning tree through the graph obtained from the cross-correlation matrix and its analysis. Essential in this method is the study of several time series simultaneously.

In research [10], the matching ratio is used to quantify the degree of similarity of the system elements

$$c_{ij} = \frac{\langle Y_i Y_j \rangle - \langle Y_i \rangle \langle Y_j \rangle}{\sqrt{(\langle Y_i^2 \rangle - \langle Y_i \rangle^2)(\langle Y_j^2 \rangle - \langle Y_j \rangle^2)}} \quad (1)$$

where i, j – series index, $Y_i = ln\, P_i\,(t) - ln\, P_i\,(t-1)$ and $P_i(t)$ value of the *i*-series at time *t*. With correlation coefficients c_{ij} a matrix of size $n \times n$ is made. It is known that the correlation coefficient can take values from -1 (totally incorrelated pair) to 1 (fully correlated pair). The matrix of correlation coefficients is a symmetric matrix with units on the main diagonal.

To understand and interpret the topological structure of the investigated system, a generalized metric is used which defined by the formula

$$d(i, j) = \sqrt{2(1 - c_{ij})} \quad (2)$$

With this definition $d(i, j)$ numerically satisfies such axioms:

i. $d(i, j) = 0$, if and only if $i = j$, the axiom is fully correlated, it can be obtained by using the same series (series numbers match) and it is almost impossible to obtain for the real market using different series;
ii. $d(i, j) = d(j, i)$ – the second axiom holds because we have a matrix of cross-correlation coefficients and, accordingly, the distance matrix *D* are symmetric by definition;
iii. $d(i,j) \leq d(i,k) + d(k,j)$ – third axiom execution can be verified numerically.

Given the nature of the values of the matrix *C*, the value in the matrix *D* belongs to [0, 2], and, $d(i, j) = 0$ means total time series similarity (in some correlation space the points corresponding to these series coincide), a $d(i, j) = 2$ means the complete opposite of the time series – in the respective space the points are at the maximum distance from each other.

The matrix *D* is used to construct the minimum spanning tree [4; 14]. For an unambiguous definition of taxonomy, a subdominant ultra-metric space is considered to be a finite topological space. In ultramodern space, elements are not placed along a single line, but in a hierarchical tree. The minimum spanning tree reflects the arrangement of the system elements and their optimal connections. The graphically minimal spanning tree is represented as a connected graph consisting of *n* vertices (nodes) and *n*-1 ribs. The minimum spanning tree has the shortest length among all trees based on the sum of the distances between the two elements. In addition, [10] shows that the minimum spanning tree based on economic indicator series reflects hidden information contained in economic time series.

The matrix *D* is also used to construct a hierarchical tree – dendrogram. Dendrogram better reflect the presence of groups of related objects – clusters – in the study system. Since the two trees are based on the same information, they are complementary and visualize each of their specific information, and together they allow for a more detailed analysis of this system.

Both ways of visualizing the connections between points make it possible to examine the presence and mutual location of objects of the system under investigation, which are grouped into clusters. In each cluster, objects are more similar to each other than to the objects of any other cluster, and therefore the distance between objects within the cluster is smaller than those of different objects.

In general, cluster search methods – clustering – form several major families:

1. hierarchical agglomerative methods;
2. hierarchical divisive methods;
3. iterative techniques;
4. methods for determining modal densities;
5. factor methods;
6. condensation methods;
7. graph-based methods.

In the proposed research we use methods belonging to the group of hierarchical agglomerative methods. This group of methods has been chosen for the following reasons. First, the algorithms of the group methods are simple enough to implement due to their iterative nature, since the sample of object pairs is performed sequentially and the entire $n \times n$ matrix is checked for n $(n–1)/2$ pairs. Second, the sequence of clusters is easily visualized by the dendrogram, and the corresponding minimum spanning tree provides additional information. The dendrogram itself for n objects forms in $(n–1)$ steps. Third, the result of a simple construction algorithm is that the interpretation of the results is fairly simple with relatively rich information on the structure of the system and the relationship between its elements.

The easiest way to construct a minimum spanning tree is the following. The points are selected sequentially, starting with the pair of points nearer and gradually changing the pairs in increasing order of the distance between the points in them. When analyzing another pair of points (o_i, o_j), the distance between which d_{ij} can be several:

(1) both points meet for the first time – then a new cluster is formed with the distance between its elements d_{ij};
(2) one of the points already belongs to some cluster – then a second point with distance from other points is assigned to the same cluster d_{ij};
(3) each of the points belongs to different clusters: then the clusters to which the points belong are merged into a large cluster with the distance between the subclusters d_{ij};
(4) both points belong to the same cluster – minimum spanning tree does not change.

From the above distribution of points by clusters, the distance between points is used as a measure of the similarity of the examined objects, with the objects being compared in pairs. This method is the easiest to understand and is called the single-link method [16]. The main disadvantage of the method is the appearance of so-called “chains” – sequences of “elongated” up clusters on dendrogram. This will be seen in the next section.

In the event that, in the search for a cluster to be included, all distances from a given point to the points of the cluster are analyzed and a cluster with the largest number of points within a distance of not more than some threshold distance to a given point is selected, the method of complete links is obtained [17]. Because of the more stringent rule of searching for such objects, the method creates more compact clusters. Although the method has no deficiency in the single-link method, it can also produce an inaccurate structure of the system under consideration, despite the compactness of the found clusters.

In order to eliminate the disadvantages of single-link and complete links methods, the average link method was proposed by the authors [17]. In this method, when searching for the cluster to which the point will be attached, the average distance from the point to the points of each of the clusters is estimated, and the lowest average distance cluster is chosen as the final cluster, but not more than some given threshold distance. A modification of the method can also be compared not with the average distance to the points of the cluster, but with the distance from the given point to the center of mass of the cluster. Note that it is the average link method that is widely used in social sciences.

The Ward's method was also developed to optimize the minimum dispersion within clusters. During the operation of the method, the optimum value of the target function of the sum of the squares of deviations is sought. According to Ward's method, each step into a large cluster consists of those groups of objects for which the sum of the squares of deviations receives the least increment. The method shows a tendency to search for clusters of roughly the same size and hyperspherical shape. The Ward's method is also widely used in the social sciences [1].

We have conducted a study and comparative analysis of economic performance using all four methods to determine the type of economic information that can be obtained by using different similarities in the search for clusters.

The study uses EU Member States' exports and imports of goods and services. The data cover the period from 2006 to 2019. In order to monitor the dynamics of structural changes in the links between countries, the general period was divided into intervals: first – 2006–2010, second – 2011–2015, third – 2015–2019. The analysis used data for all EU Member States at the time of the calculations. All data received from the official statistics site [7].

4 Results and discussion

As part of this approach the tools were implemented and calculations were made in the Matlab.

As mentioned above, the visualization of the results can be performed both using the minimal spanning trees and using the dendrograms. For example, in figure 1 shows an image of a possible minimal spanning tree [6].

The figure shows information about the mutual location of the economic agents under study, the presence of separate clusters, as well as some relationships between clusters. However, due to the fact that the minimal spanning trees mostly do not reflect the closeness of links (or the strength of links), it is very difficult and often impossible to talk about a certain number of clusters, the location of economic agents in clusters, and so on. The use of additional information about the strength of connections in clusters greatly complicates the procedure of visualization of the minimum scanning tree, and often makes it impossible.

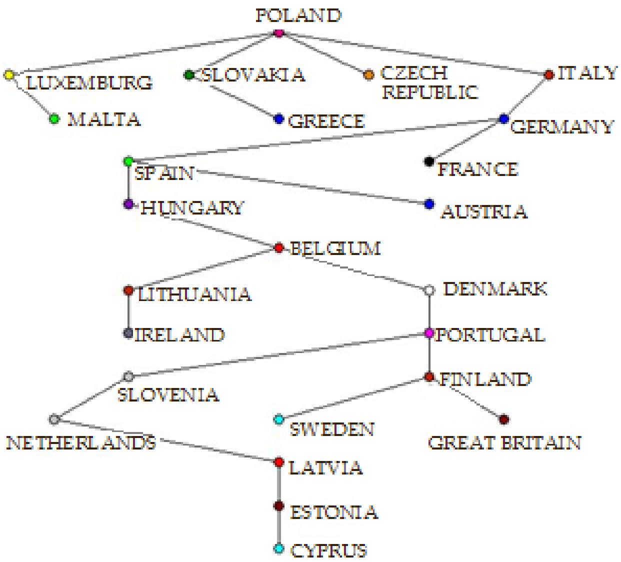

Fig. 1. The minimal spanning tree of the dynamics of exports of EU goods for 2000-2006.

Instead, the dendrogram shows both the closeness of the links between economic agents and, when using the criterion of minimal communication within the cluster, the presence and configuration of clusters. That is why to study the structural shifts and the possibility of their reflection by each of the methods used, we compare the dendrograms obtained for each of the periods by each method. On the dendrograms represented in the article the blue vertical lines from the values of the countries included in the EU before 2000, and the red lines from the countries included in the EU after 2000.

Figures 2-4 shows the dendrograms obtained for the links between the EU Member States in export of goods using the Single link method calculated for the respective periods referred to earlier.

First of all, there is a large cluster with close links, including Austria, Germany, Portugal, Spain, Italy, Belgium, the Netherlands, France, Denmark, Sweden. Note the gradual weakening of Denmark and Sweden with the cluster countries as the time period close to 2019.

Among the EU member countries that have joined since 2000 Slovenia, the Czech Republic, Hungary, Poland, Slovakia are permanently in the cluster and the link with Romania has been strengthened since 2011. In this cluster, the distance between the countries does not exceed 0.5, which corresponds to a correlation coefficient ≈ 0.7.

Over time, Malta and Cyprus have gradually become less connected to other EU countries. Note also that other countries are at a distance of 0.5-0.9 to the core cluster, which corresponds to correlation coefficients from ≈0.7 to ≈0.9. Also significant is the gradual reduction of the distance between these countries and the core cluster in proximity 2019, which can be attributed to the increased coherence in the trade strategy for the EU countries.

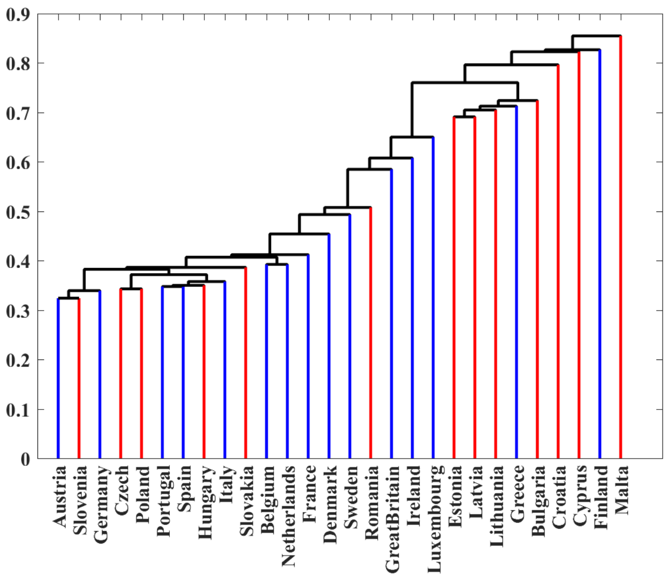

Fig. 2. Dendrogram of Links for Export movements in the European Union for the period 2005-2010, Single link method.

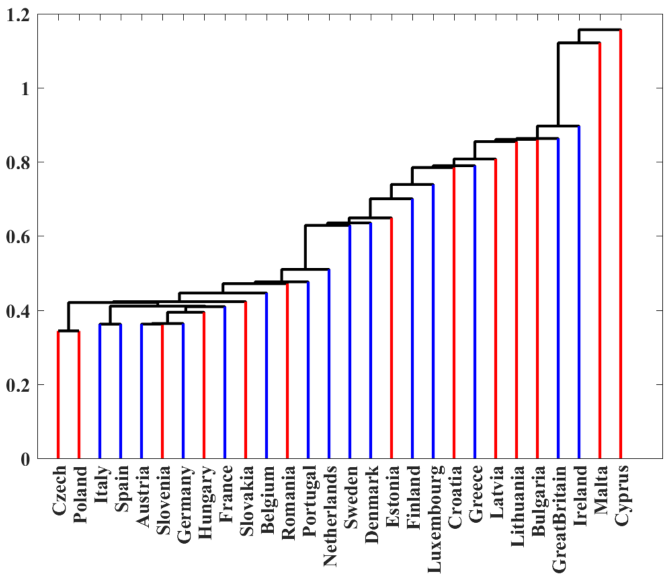

Fig. 3. Dendrogram of Links for EU Export movements in the European Union for the period 2011-2015, Single link method.

The following results were obtained when analyzing the relationship between EU countries in terms of exports of goods using the method of averaging.

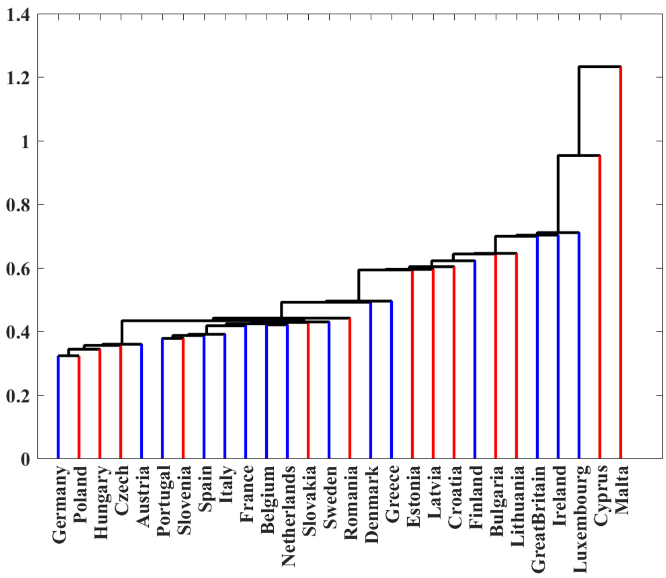

Fig. 4. Dendrogram of Links for Export movements in the European Union for the period 2016-2019, Single link method.

In the first study period there is one powerful and three small clusters with intracluster distances less than 0.5. The powerful cluster includes, inter alia, Belgium, the Netherlands, Italy, Germany, France, and Hungary and Slovakia. Up to three small clusters are: 1) Austria and Slovenia; 2) Czech Republic and Poland; 3) Portugal and Spain. As can be seen, in this case the countries in the small clusters are geographical neighbours and can explain the similar trade strategy of the countries in one cluster. However, inter-cluster links are weak, which means own trade strategies within the cluster.

In the transition to dendrograms received in later periods, this trend towards the location of geographically adjacent countries remains largely unchanged, but also a noticeable tendency to reduce cluster power with strong internal link and weak interlaced links, which even corresponds to anticorrelated behavior of the countries.

Note the existence of a large group of countries identified by this method as countries with a relatively dedicated trade strategy. Another important feature is the continuation of the trend of Cyprus and Malta until full separation of trade strategies from other EU Member States.

Figure 5-7 shows the dendrograms obtained for the relationship between the EU Member States in export using the Complete link method calculated for the respective periods. In the obtained dendrograms, there are 4 to 5 small clusters with distances up to 0.5. In the first time period (2005-2010) there are 4 clusters with this characteristic:

1) Austria and Slovenia; 2) Czech Republic and Poland; 3) Portugal, Spain, Italy, Germany; 4) Belgium, Netherlands, Hungary, France, Slovakia. In this case the principle of geographical link within the clusters and the very weak link between the first named cluster and other EU countries are observed. At the same time, all other countries outside these clusters have weak links, ranging from 0.5 to 1.0.

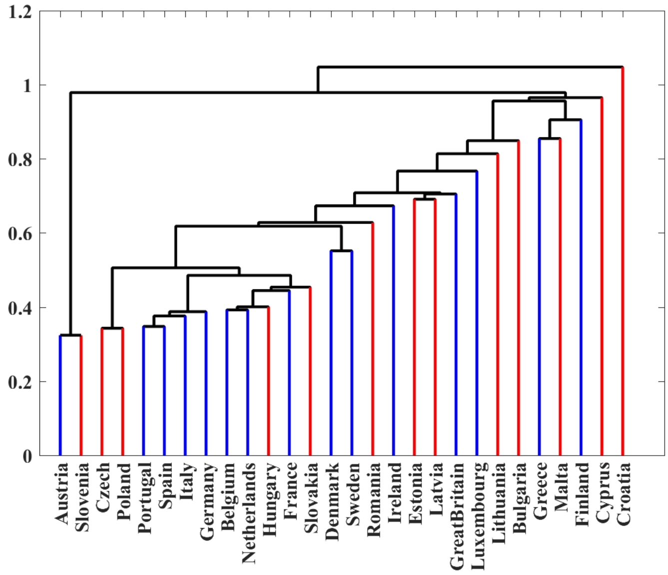

Fig. 5. Dendrogram of Links for Export movements in the European Union for the period 2005-2010, Complete link method.

However, several countries – Croatia, Cyprus, Finland, Greece, Malta and Finland - are virtually on the sidelines because, while Greece, Finland and Malta could be grouped under one cluster, the links between them are so weak that the boundaries of the cluster are extremely blurred.

In the next time period, there is some reformatting of the main clusters (figure 6): 1) Czech Republic, Poland; 2) Italy, Spain; 3) Austria, Slovenia, Germany, Hungary, Slovakia, Belgium, France; 4) Portugal, Romania. The trend towards a joint trade strategy continues, owing to the geographical proximity of countries, as well as the presence of a large group of countries with relatively different trade strategies. Malta and Cyprus are also gradually moving away from the trade strategies of any other country.

In the last time period (figure 7) five clusters with strong links within can be identified again. Growth of cluster capacity is important: 1) Germany, Poland, Hungary; 2) Portugal, Slovenia; 3) Italy, Spain, Austria, France; 4) Belgium, Netherlands; 5) Czech Republic, Slovakia, Sweden, Romania, Denmark. Thus, the number of countries in the observed clusters increased to 16 in the last period, which can be explained by the tendency of Governments to adopt joint trade policies. In the time period under study, countries are grouped into clusters along geographical lines. The trade strategies of Malta and Cyprus can also be further isolated.

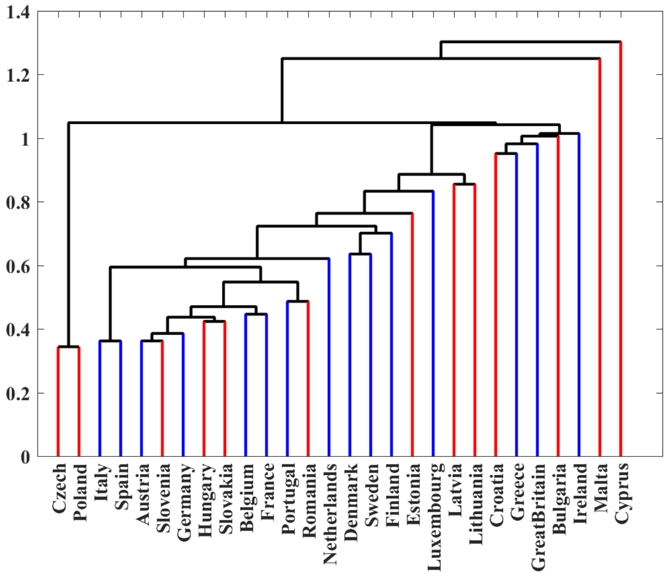

Fig. 6. Dendrogram of Links for Export movements in the European Union for the period 2011-2015, Complete link method.

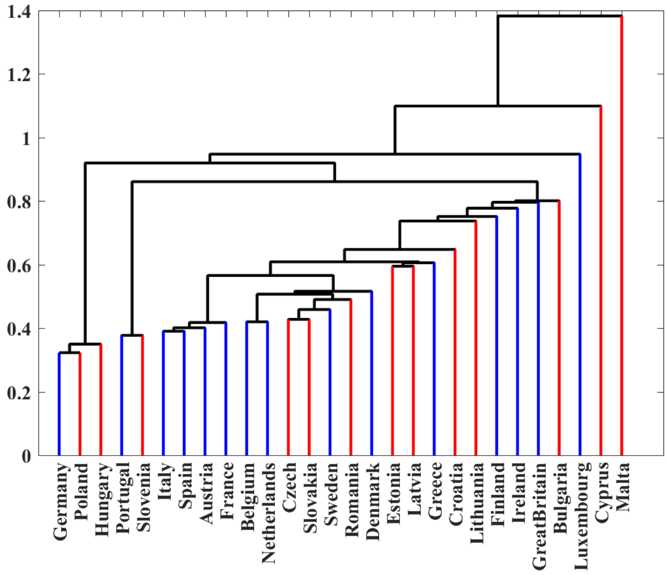

Fig. 7. Dendrogram of Links for Export movements in the European Union for the period 2016-2019, Complete link method.

Figures 8-10 shows the dendrograms obtained for the inter-EU relations for merchandise exports using the Ward's method, calculated for the respective periods.

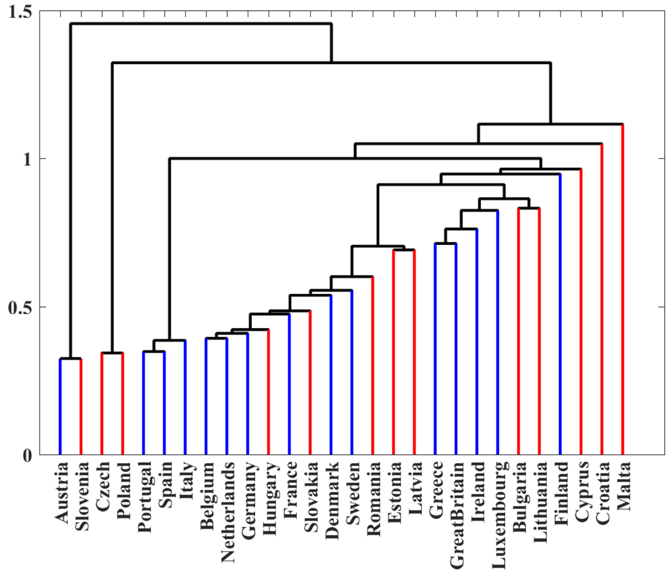

Fig. 8. Dendrogram of Links for Export movements in the European Union for the period 2005-2010, Ward's method.

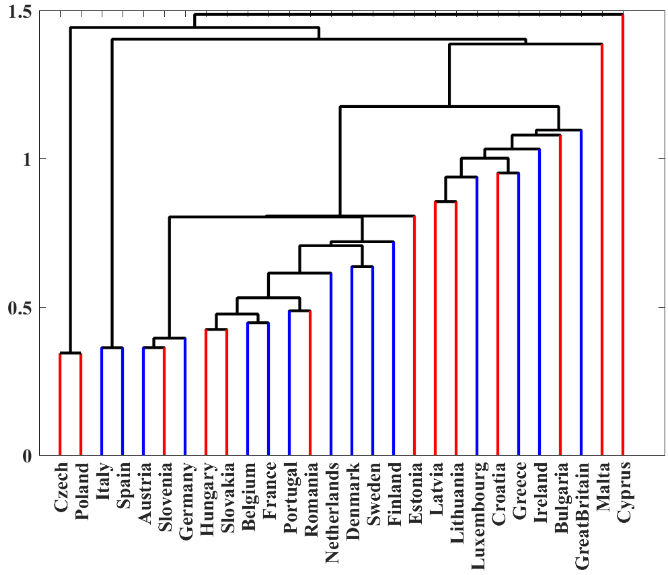

Fig. 9. Dendrogram of Links for Export movements in the European Union for the period 2011-2015, Ward's method.

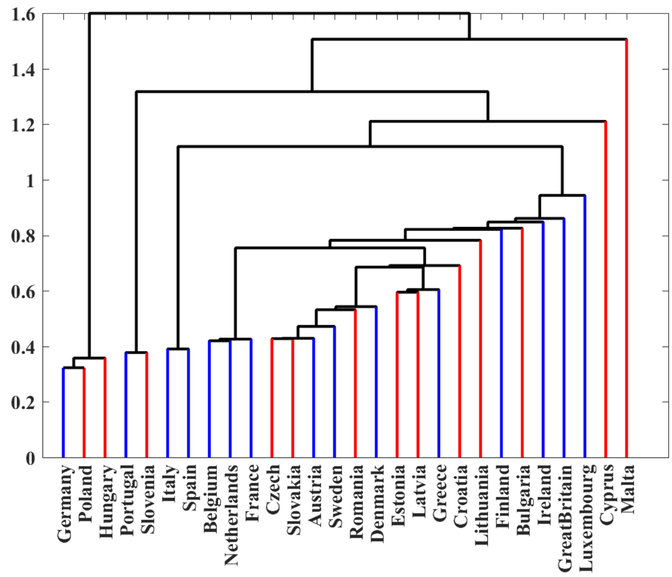

Fig. 10. Dendrogram of Links for Export movements in the European Union for the period 2016-2019, Ward's method.

In the first time period (2006-2010) there are four clusters, three of which are small and the fourth is quite powerful (figure 8). Small clusters are: 1) Austria and Slovenia; 2) Czech Republic and Poland; 3) Portugal, Spain and Italia. The following EU countries have joined cluster 4: Belgium, Netherlands, Germany, Hungary, France, Slovakia. There is also a tendency to join the cluster, but with slightly weaker links, by the following countries: Denmark, Sweden, Romania, Estonia, Latvia. For the results obtained, the principle of geographical proximity continues to be a key one, although it is weaker than the one of complete link. On the other hand, the trend towards Malta and Cyprus' own trade policies continues.

There is some slight reformatting of the clusters when moving to the next period, but the vast majority of countries continue to be linked to the same countries (figure 9). For this time period, there is a slight weakening of the most links within the clusters and a corresponding weakening of the inter-cluster bonds. Malta and Cyprus continue to pursue their own trade strategy. For Portugal and Germany clusters are changing, but it is not possible to tell by the methods used whether these countries have moved to other clusters or have joined countries from other clusters in these clusters.

There is also a significant trend in the results of the weakening of the cluster bonds, which is reflected in the shift of the median value from about 1 side of the increase in distance to 1.5.

In the last time period studied, the number of clusters with strong intra-cluster linkages is 5. The clusters comprise the following countries: 1) Germany, Poland, Hungary, 2) Portugal, Slovenia; 3) Italy, Spain; 4) Belgium, Netherlands, France; 5) Czech Republic, Slovakia, Austria, Sweden. Here, it is clear that the principle of building trade strategies on the basis of the geographical location of countries has been maintained and somewhat strengthened. The trend towards Malta and Cyprus' own strategy, as well as the general trend towards loosening of inter-cluster links, continues. Thus, the following conclusions were drawn from the analysis of the results obtained by the selected methods from the export data of the EU Member States.

The Complete link method and the Ward's method have produced rich and more consistent information than the other two methods. The most detailed information was given by the Complete link method, due to the combination of methods, as already mentioned in the previous section, the advantages of the Single link method and the average link method. Therefore, the Complete link method was chosen for further analysis.

On the clustering of countries and the restructuring of clusters. There are a steady number of clusters during the study periods, ranging from 3 to 5, with close links within countries. There is almost always one more powerful cluster and several smaller ones – 2-3 countries each of clusters. Within clusters, countries are mostly geographically grouped and links between clusters are significantly weaker. This is logically due to the similarity of natural resources and the climate of geographically adjacent countries, which results in a large number of such products, particularly agricultural products. Varying degrees of industrial development within countries adjust their cluster distribution to produce unexpected inter-cluster links. Looking at the EU countries with more advanced economies, one can observe a tendency for smaller economies to join, which is also understandable. Analysis of structural changes towards 2019 shows a trend towards some increase in cluster capacity, may indicate the desire of EU member countries for mutual assistance and common economic policies.

Based on the interim conclusions on the applicability of the chosen methods, analyse the imports of goods by EU Member States over the selected time intervals, using the Complete link method.

In the next step, we analyzed the import of goods from EU member states during the study period using the Complete link method.

From the dendrogram of the links of imports of EU Member States for the period 2005-2010 the presence of four small clusters is clearly visible: 1) France, Spain; 2) Czech Republic, Slovakia, Italy; 3) Austria, Slovenia, Hungary, Poland; 4) Belgium, Netherlands, Portugal. Most of the represented countries are those that joined the EU in the last century, while most of the countries in these clusters have developed economies. The clusters themselves are small, ranging from two to four countries. Linkages between clusters are weaker, but do not exceed 1 (which corresponds to a correlation coefficient of 0.5). As in the case of exports of goods, there is a significant separation of the import strategy for Cyprus and Malta, to which Luxembourg has also acceded, from other EU members. In addition, you can see three more "blurred" clusters, which include most EU members that have remained.

Next, we analyzed the dendrogram of the links of imports of EU Member States goods received over the period 2011–2015. In this case, three clear clusters of low power and one larger, less clearly delineated cluster are visible. The first three are: 1) France, Italy; 2) Germany, Poland; 3) Austria, Slovenia, Hungary. The countries included in the large cluster are: Belgium, Netherlands, Czech Republic, Slovakia, Portugal, Romania, Spain Compared to the previous period, Italy, Spain and Germany have moved to other clusters, while the remaining countries have made little change in their location, and most of them have even strengthened inter-cluster links. Remaining Malta and Cyprus, other countries continue to establish several clusters less than in the previous period continue to create multiple clusters of less clear shape.

At last, we analyzed the dendrogram of the EU Member States import links for the period 2016-2019. Using an intracluster distance criterion of 0.5 or less, three clear clusters are obtained: 1) Germany, Hungary; 2) France, Italy, Austria, Poland, Spain; 3) Czech Republic, Netherlands. However, another clear cluster can be distinguished from intracluster distances of 0.5 Croatia, Romania, Portugal, Estonia, Finland, Belgium, Slovenia. Intracluster links continue to be weak, and there is also a clear trend towards an increase in the number of countries with their own import strategies; in the period under study, there are already four.

Thus, an analysis of imports of goods over the full period shows a tendency to enlarge groups of EU member States with similar import strategies. However, geographical groupings are almost non-existent. This can be explained, in particular, by the different needs of countries in the groups of imported goods, primarily by the industrial groups developed within countries. During the full period, there has been a trend towards clustering, that is to say, an increase in the number of countries with similar import strategies, which could mean greater specialization of countries.

In figures 11-13 presents the dendrograms obtained during the analysis of the dynamics of services' exports by EU member states for the studied periods.

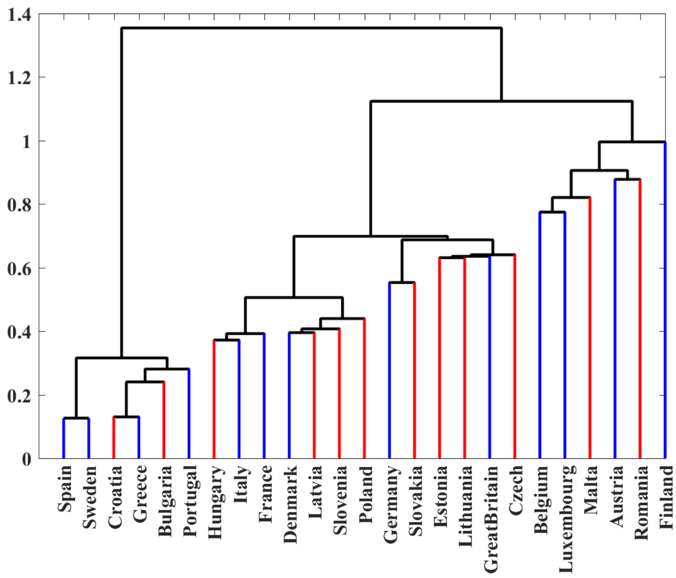

Fig. 11. Dendrogram of Links for service export movements in the European Union for the period 2005-2009, Complete link method.

Figure 11 presents a dendrogram of the EU Member States' relations on the dynamics of services exports for the period 2005-2009. The drawing clearly shows two distinctly strong enough clusters: 1) Spain, Sweden, Croatia, Greece, Bulgaria, Portugal; 2) Hungary, Italy, France, Denmark, Latvia, Slovenia, Poland. Note also those expressed in the clusters: two in each of the clusters. Such a structure could mean a similar strategy for exporting services to a leather cluster with some specialization under clusters. Also important is the very weak link between the identified clusters, which can be explained by the significantly different strategies for service delivery across the different clusters. Compared to the goods market, there are no countries with unique performance in the services export market for the period under study.

The market for services exports is characterized by the consolidation of clusters and the strengthening of intercluster links (figure 12).

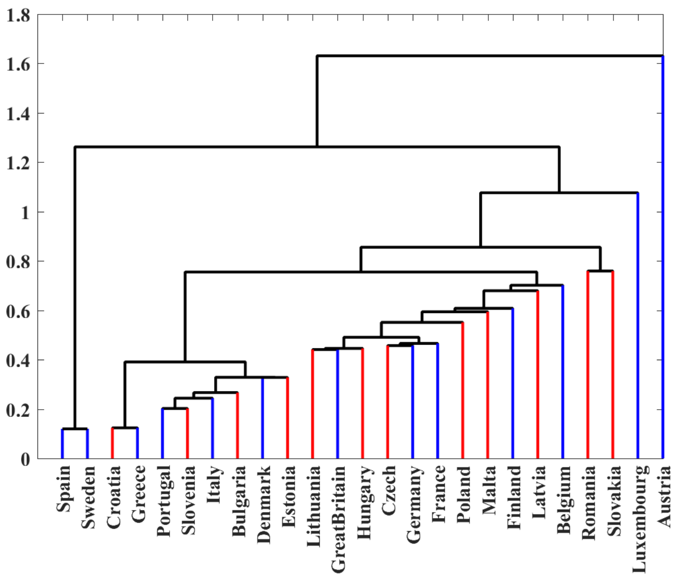

Fig. 12. Dendrogram of Links for service export movements in the European Union for the period 2010-2014, Complete link method.

Four clusters can also be distinguished during this period: 1) Spain, Sweden; 2) Croatia, Greece; 3) Portugal, Slovenia, Italy, Bulgaria, Denmark, Estonia; 4) Lithuania, United Kingdom, Hungary, Czech Republic, Germany, France. In addition to the fact that the number of countries has increased, that has been distributed by clusters in comparison with the previous period – from 13 to 16 – the last of the listed cluster also has several "satellites" that have not been assigned to it, as they have weak links with other countries of the cluster, however, can also be interpreted as belonging to the cluster. There is no territorial unification of countries within the clusters. In addition, Luxembourg and Austria are two countries with unique performance in the services export market.

Figure 13 shows the dendrogram of the links for service exports over the period 2014-2019. The most important distribution of almost all EU Member States by clusters: we have 5 clusters of power 2, 5, 2, 7, 6. Only Finland, Great Britain, Austria are excluded from the clusters. The connections within the clusters do not exceed 0.5. That is, at the end of the study period, we have an increase in the integration of countries into the market of services exports. This may likely indicate a shift in specialization in the EU countries. This view is also supported by the significantly weaker inter-clusters links.

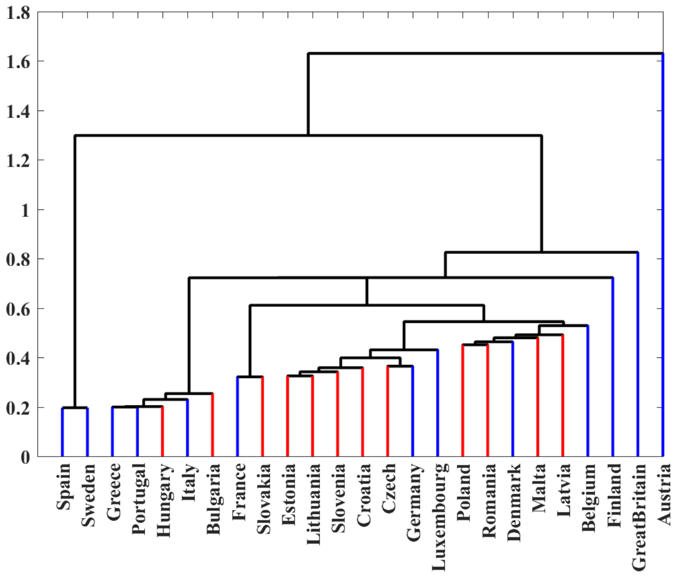

Fig. 13. Dendrogram of Links for service export movements in the European Union for the period 2014-2019, Complete link method.

In summary, the analysis of services exports shows a significant restructuring of the European services market, a tendency of countries to specialize in the market and form large groups of countries with similar dynamics of services exports.

Finally, the latter analysed the behaviour of EU Member States in the services import market.

At first step the dendrogram of the EU Member States' links for imports of services for the period 2005-2009 were analysed. There are four clusters: 1) Germany, Slovenia; 2) Estonia, Latvia, Austria, United Kingdom; 3) Czech Republic, Sweden; 4) Hungary, Slovakia, Spain, Italy, Poland. Dendrogram shows strong links between countries within clusters and much weaker linkages between clusters. Malta and Finland have demonstrated their own behaviour in the services import market. Some of the other countries can be merged into another, more diffuse, cluster, but the inter-cluster links will be significantly weaker, so we did not consider these countries as a separate cluster.

From dendrogram with the links between the countries for the period 2010–2014 were obtained next results. Two clear clusters can be distinguished: 1) Italy, Slovenia;

2) Austria, Germany, Latvia, Poland. Other clusters that could be created have weak inter-cluster links and are therefore not considered. Note the group of countries – Greece, Luxembourg, Lithuania, Malta – with their own, unlike other countries, dynamics of services imports.

The last dendrogram (see the figure 14) with the links for service import movements in the European Union for the period 2015-2019 makes it possible to distinguish three clusters. The first consists of Germany and Spain. The second is from the countries which in turn constitute three subclusters: 1) Italy, Poland; 2) Austria, Slovenia, Latvia; 3) Bulgaria, Portugal. The dendrogram in figure 21 makes it possible to distinguish three clusters. The first consists of Germany and Spain. The second is from the countries which in turn constitute three subclusters: 1) Italy, Poland; 2) Austria, Slovenia, Latvia; 3) Bulgaria, Portugal.

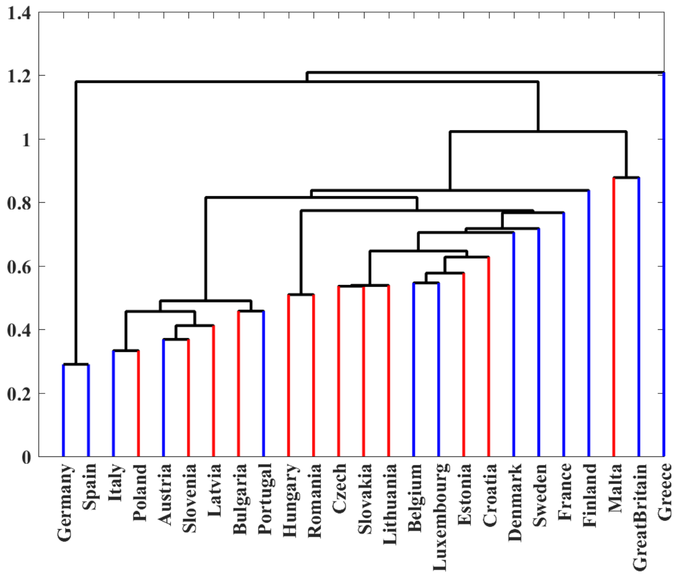

Fig. 14. Dendrogram of Links for the dynamics of imports of services of EU countries for the period 2014-2019, Complete link method.

In summary, the market for services import is characterized by a largely weak correlated behaviour, which is due to the significantly different needs of countries for services. By the end of the period under review, linkages between countries are somewhat weakened and there has been a steady shift from one cluster to another in the pattern of service imports. The behaviour of countries in this market is difficult to characterize and this market requires, first and foremost, further research.

Thus, applying the minimum spanning trees analysis, in particular dendrograms, at successive intervals in the historical time series of exports and imports of goods and services of the EU Member States, it is possible to track changes in the structure of relations between countries that have occurred during this period. In addition, graphical visualization allows quick analysis of the formed clusters, to identify which countries are part of a cluster, i.e., to determine their homogeneity.

5 Conclusions

As a result of the analysis, a number of countries were identified, in particular, Malta, Cyprus, whose links with other EU countries are gradually weakening, which can be explained by the use of its own economic development strategy. Instead, for a large group of countries, there is a strengthening of links and consolidation of clusters over time, which means focusing on a common strategy of economic development. Among the latter countries, there are, first of all, economically powerful EU countries, such as Germany, France, Spain, etc.

In addition, the analysis of relations between countries showed the formation in the existing clusters the smaller clusters of countries, which are located geographically close one by another. This can be explained by additional similar climatic conditions, natural resources and so on.

Thus, the construction of minimum spanning trees and their separate form – dendrograms – allowed to investigate structural and dynamic changes in the trade relations of the EU Member States. On the basis of the analysis made and by comparing the results with the political and economic situation in the market under study. It can be said that the accession of new countries to the EU and the global crises are transforming the trees' structure and that new links between countries are being reformatted and created. The links' structure is also influenced by the economic situation of countries, the natural resources of countries and the degree of development of countries.

References

1. Blashfield, R.K., Morey, L.C.: A comparison of four clustering methods using MMPI Monte Carlo data. Applied Psychological Measurement **4**(1), 57–64 (1980)
2. Caporale, G.M., Sova, A., Sova, R.: Trade flows and trade specialisation: The case of China. China Economic Review **34**, 261–273 (2015). doi:10.1016/j.chieco.2015.03.010
3. Chakravarty, S.L., Chakrabarty, R.: A Gravity Model Approach to Indo-ASEAN Trade-fluctuations and Swings. Procedia – Social and Behavioral Sciences **133**, 383–391 (2014). doi:10.1016/j.sbspro.2014.04.205
4. Cormen, T.H., Leiserson, C.E., Rivest, R.L., Stein, C.: Introduction to Algorithms, 3rd edn. MIT Press, Cambridge (2009)
5. D'Agostino, A., Modugno, M., Osbat, C.: A Global Trade Model for the Euro Area. Finance and Economics Discussion Series 2015-013. Board of Governors of the Federal Reserve System, Washington (2015). doi:10.17016/FEDS.2015.013
6. Danylchuk, H., Kibalnyk, L., Burlaienko, T., Dubinina O.: Modelling of trade relations between EU countries by the method of minimum spanning trees. Advances in Economics, Business and Management Research **95**, 217–221 (2019). doi:10.2991/smtesm-19.2019.43
7. Eurostat. https://ec.europa.eu/eurostat (2020). Accessed 17 Aug 2020

8. Kibalnyk, L.O., Danylchuk, H.B.: Analiz naslidkiv vykhodu Velykobrytanii zi skladu YES merezhno-entropiinymy metodamy (Analysis of the consequences of the UK exit from the EU through network-entropy methods). Mizhnarodni Vidnosyny, seriia Ekonomichny nauky 11. http://journals.iir.kiev.ua/index.php/ec_n/article/view/3196 (2017). Accessed 12 May 2020
9. Makhov, S.A.: Dinamicheskaja model vneshnei torgovli stran BRIKS (BRICS trade dynamic model). Preprinty IPM im. M. V. Keldysha 128 (2016). doi:10.20948/prepr-2016-128
10. Mantegna, R.N.: Hierarchical Structure in Financial Markets. European Physical Journal B **11**(1), 193–197 (1999)
11. Minford, P., Xu, Y.: Classical or Gravity? Which Trade Model Best Matches the UK Facts? Open Economies Review **29**, 579–611 (2018). doi:10.1007/s11079-017-9470-z
12. Natale, F., Borrello, A., Motova, A.: Analysis of the determinants of international seafood trade using a gravity model. Marine Policy **60**, 98–106 (2015). doi:10.1016/j.marpol.2015.05.016
13. Ortiz-Ospina, E., Beltekian, D.: Trade and Globalization. https://ourworldindata.org/trade-and-globalization (2018). Accessed 17 Aug 2020
14. Sedgewick, R., Wayne, K.: Algorithms, 4^{th} edn. Addison-Wesley, New York (2014)
15. Shen, B., Zhang, J., Zheng, Q.: Exploring multi-layer flow network of international trade based on flow distances. arXiv:1504.02361v1 [physics.soc-ph] (2015). Accessed 18 May 2020
16. Sneath, P.: The application of computers to taxonomy. Journal of General Microbiology **17**(1), 201–226 (1957)
17. Sokal, R.R., Michener, C.D.: A statistical method for evaluating systematic relationships. The University of Kansas Scientific Bulletin **XXXVIII**(II, 22), 1409–1438 (1958)
18. Soloviev, V.N., Belinskiy, A.: Complex Systems Theory and Crashes of Cryptocurrency Market. Communications in Computer and Information Science **1007**, 276–297 (2019). doi:10.1007/978-3-030-13929-2_14
19. Soloviev, V.N., Yevtushenko, S.P., Batareyev, V.V.: Comparative analysis of the cryptocurrency and the stock markets using the Random Matrix Theory. CEUR Workshop Proceedings **2546**, 87–100 (2019)
20. Tabachkova, N.A., Krachkovskiy, V.V.: Design of processes of international agglomeration. Scientific Bulletin of the Uzhgorod University, Series International economic relations and world economy 6(3), 74–77 (2016)