ECOLOGICAL AND ECONOMIC DEVELOPMENT DIMENSIONS OF THE COUNTRIES WITH THE USE OF CLUSTER ANALYSIS TOOLS

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Abstrac: The article examines the features of the application of cluster analysis to assess the level of greening the economies of the countries of the world. A sample of indicators on which the economy of developed countries is based, in particular, the standard of living in the country, anthropogenic load, energy intensity of the economy, has been carried out. Taking into account these indicators, the countries of the world were clustered into three main groups and the fourth is presented as general (background) data. The features of the greening of the economies of the countries of each group are characterized, the similarities and differences are determined. A hypothesis is put forward about the relationship between the level of economic development and anthropogenic load in states.

Key words: clustering, sustainable development, environmental policy, environmental and economic indicators, greening, economic development, environmental safety.

JEL: Q51, Q58. O50, O52.

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1. Introduction

In the first two decades of the XXI century, many countries have formed a clear trend towards greening the economy and the introduction of "green" technologies, both at the level of consumers and at the level of national economies of the developed world (Santoalha & Boschma, 2020). This occurs, inter alia, as part of the implementation of the concept of sustainable development under the auspices of the United Nations (hereinafter referred to as the «UN»). When studying the process of greening the national economies of different states, it becomes necessary to identify groups with similar characteristics (distinguishing regions based on the quantitative characteristics of the objects combined in them) for their further study.

The basis for our study was the work of foreign scholars who have dealt with the issues of regionalization processes. The ideas of regionalism are based on the need for national economic regulation and approval of national social standards (Berner, 2004). The regions, at the expense of the governing bodies, formed an economic policy that was aimed at expanding the market and integrating weak regions into the international economic space. After the 1980s, the tendencies (Malecki, 2012; Putnam, 1993) of transformation of the priorities of regionalism from economic to social are gaining strength. Since the end of the XXth century, the vector of regionalism has been supplemented by the formation of the idea of social identity, the idea of self-determination of the people and nation (Núñez Seixas, 2001, Olsson, 2009). Regionalization also influences the political activities of regional governments, calling for greater autonomy and distribution of central and regional powers of government (Keating, 2016). Since the beginning of the XXst century, sectoral and class interests have become the major factors in the construction of regions (Keating and Wilson, 2014), within which horizontal and vertical relations between classes and government can be noted. Thus, the private economic sector chooses a local place for investment and provides infrastructure, labor and technological innovation (Keating, 2016), trade unions advocate for national standards for improvement, social partnership, and social compromise at the local and state levels (Keating, 2016), and groups of environmentalists exercise social influence at the local level, although the regulation of the issue of environmental protection is entrusted to regional governments.

The idea of dividing countries into regions only on the basis of their level of economic development does not reflect the realities of our time, due to the fact that regionalism was originally based on the idea of increasing economic efficiency, but over time this idea has evolved, the emphasis has shifted towards social (quality of life), cultural (self-determination of nations), political (governmental activities and cooperation) and environmental (ensuring environmental security) activity in the region.

The coherent and harmonious development of all countries in the region requires a regional development strategy. This strategy should take into account the differences and peculiarities of all states of the region. To increase the effectiveness of the development strategy of the region, it is necessary to identify groups of states that have similar characteristics. This approach will make it possible to effectively divide the region into mesoregions (groups of countries) based on specific, predetermined characteristics (economic, environmental, etc.).

The question arises what characteristics should be used to determine the common features, peculiarities and differences of objects within regional associations. At the first stage, we chose the principle of division by geography, but it does not give a complete picture of the similarities or differences between countries, and does not allow us to clearly draw the boundaries of mesoregions. For our study, environmental security was defined as the main characteristic. The next step was to determine the method of delineation of the mesoregion in the European region. Due to the fact that the task was reduced to the division of objects having a set of certain characteristics into groups, the cluster analysis was chosen as a method of solving the problem. This approach works well in cases where it is necessary to divide the territory on the basis of predetermined characteristics (Methodology Report, 2017).

Although methods of cluster analysis are widely used in economics, for example, to determine the prospects for international trade within the European Union (Dziubanovska, N.V., 2016), at present the use of clustering algorithms to improve management efficiency in the field of environmental safety is not widespread.

2. Methods

In order to group countries on the basis of the level of environmental security, it is necessary to determine the indicators that will be the basis for achieving the goal.

The general conceptual approach to the indicators is that they should reflect the level of environmental security in the country, that is, they should show how effective the state's environmental policy is. The effectiveness of environmental policy directly depends on the standard of living in the country and the level of development of industrial sectors of the economy. In this case, the following characteristics of the state should be defined:

- the standard of living in the country;
- anthropogenic load (in recalculation per each inhabitant);
- energy intensity of the economy.

Although today GDP by itself cannot be an exhaustive indicator for assessing the economic development of a state, and even more so for assessing the standard of living in a state (Dynan, 2018), its use in various relative indicators, and in combination with other indicators can still be a good basis for assessing and comparing countries in various (related to economic activity) directions (Grishin, Ustyuzhanina and Komarova, 2019). In our study, we used the indicator of GDP per capita (hereinafter referred to as the "GDP"), which gives an idea of the level of economic activity in the country, and also indicates the level of income of citizens. On the basis of this indicator it is possible to make comparisons of living standards in different countries.

In order to assess the level of anthropogenic load in the country, an assessment of the impact of PM2.5 particles on human was used. PM2.5 particles can cause a variety of health problems. Among the most common are cardiovascular problems, general inflammatory processes, and asthma (Martins, Da Graca, 2018).

In this case, the atmospheric pollution effect indicator, which is calculated based on the effect of PM 2.5 particles and is described as the number of premature deaths associated with atmospheric pollution, can serve as a good indicator for assessing the level of anthropogenic load.

Energy consumption is an indicator that affects the level of environmental safety and describes the energy intensity of the economy. This is due to the fact that a large amount of pollutants is emitted into the atmosphere during energy production. The use of any fuel is associated to some degree with greenhouse gas emissions, and combined with the growing demand for energy in all countries of the world (Kgabi, Grant, Antoine, 2017), the level of energy consumption in a country is one of the main indicators of the impact of society on the environment at both at the local and global level. Based on the indicator of energy consumption in conjunction with GDP, it is possible to judge the energy efficiency of the state economy, as well as, to some extent, to assess the level of development of the industrial sector of the economy, as it is one of the main consumers of energy. The level of energy consumption serves as an indicator of how intensively the energy system in the country works, which can cause serious damage to local ecosystems if old technologies are used (Greenstone, Reguant, Ryan, and Dobermann, 2017). General information about the selected indicators was presented in Table 1.

Table 1
Selected indicators and their characteristics

Indicator	Units	Characteristic
GDP per capita	Thousand. USD per person	Indicator of the socio-economic development level of the state.
Power consumptio n	Mln. tons of oil equivalent	The indicator shows the total energy consumption in the country. Calculated as the sum of energy produced and imported (used) minus exported energy, energy is stored in international bunkers
Air pollution effect	The number of premature deaths associated with atmospheric air pollution with particulate matter per 1 million population	Indicator showing the impact of the environment on humans.

Source: compiled by the author himself.

The figures were taken from the official website of the Organization for Economic Co-operation and Development (OECD) for the period from 2000 to 2018. Due to the need to process a large volume of OECD data and delays in the provision of data by countries around the world, 2018 is the last year for which the necessary information was available at the time of this Article.

The data sample consisted of information from 44 countries of the world, for which all the necessary set of statistical information was present. The study uses data from all 44 countries, but the main focus of the Article was on the European Region and some countries bordering it.

Analyzing the European region, all of its countries can be divided into clusters. It is assumed that there are several clusters of states that have some common tendencies in the conduct of environmental and economic policy, which make it possible to successfully combine a high standard of living and a low anthropogenic load.

All calculations were carried out by the Google Colaboratory environment (https://colab.research.google.com/). Since the data have a large difference in dimension, they were normalized using the z-score technique (Ali & Faraj, 2014).

In this approach, the mean value in the array is zero, and the distance is measured as the number of standard deviations.

For this study, it is necessary not only to divide the data array into subsets, for which such clustering algorithms as K-means, mean-shift clustering are suitable, the task is precisely to select groups of objects (countries) with common characteristics. To solve this problem, it is appropriate to use an algorithm based on the analysis of the density of data points DBSCAN (Creţulescu, Morariu, Breazu & Volovici, 2019). The use of this algorithm will allow to allocate an area of data compaction, in our case will mean a subset of elements with similar characteristics.

3. Research results

In the resulting set of points, where each point represents one of the states from the general list, it was possible to identify 3 groups of states and a general group (the fourth), representing general (background) data. We can say that in this case there are two opposite options: the first is the countries with high living standards (GDP), low anthropogenic load and energy consumption, and the second is the countries with low living standards, high value of the effect of atmospheric pollution, related to atmospheric pollution, and energy consumption.

The data space and selection of groups are shown in Figure 1. Objects that are not included in any of the three groups are highlighted in purple. The division of countries into groups is shown in Table 2.

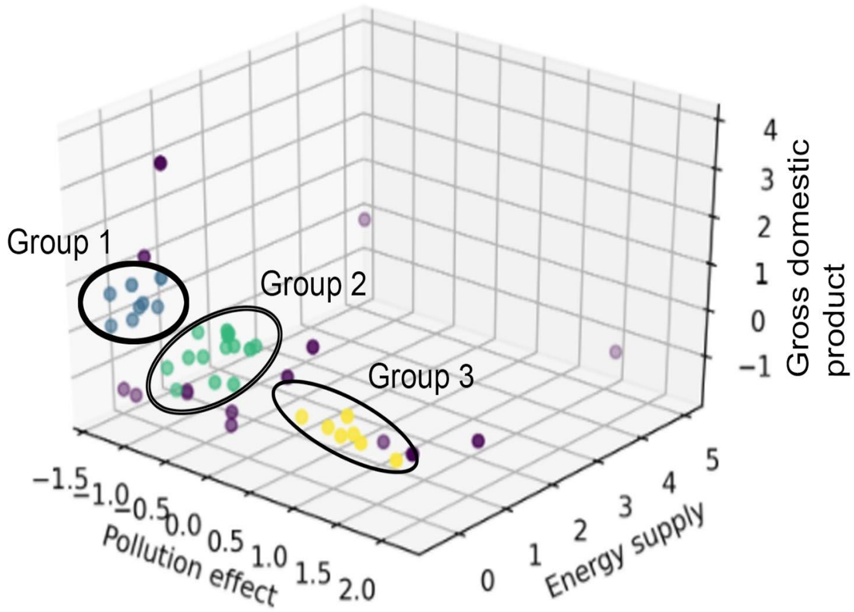

Fig. 1 Clustering of countries of the world with color highlighting of groups.

The unit on the coordinate axis is equal to one standard deviation in the plural.

Table 2
World Countries clustering by indicators based on the table 1

	Group			
	first group of countries	second group of countries	third group of countries	Not included in the group (general pattern haven't been found)
Country	Australia, Canada, Finland, Iceland, New Zealand, Norway, Sweden, Switzerland	Austria, Belgium, Denmark, France, Japan, South Korea, Netherlands, Portugal, Spain, Great Britain, Chile, Estonia, Israel, Slovenia	Czech Republic, Greece, Hungary, Poland, Slovakia, Turkey, Latvia	Germany, Ireland, Italy, Luxembourg, Mexico, United States, Argentina, Brazil, China, Colombia, Costa Rica, India, Lithuania, Russia, South Africa

Source: compiled by the author himself.

The averaged values of the indicators among the countries of each group are shown in Table 3.

Table 3
Average values of indicators among the countries of the group

Indicator	Group		
	first group of countries	second group of countries	third group of countries
GDP per capita	51212,9	40466,1	28845,6
Energy consumption	71,1	109,3	49,5
Air pollution effect	178,7	315,2	550,1

Source: compiled by the author himself.

Based on the data obtained after the selection of groups of countries, a map of the world and Europe was compiled with the application of color keys of the groups (Fig. 2).

Color keys:

- Red – 1st group
- Blue - 2nd group
- Orange - 3rd group
- Turquoise - countries not included in any group
- Gray - countries for which data are not available

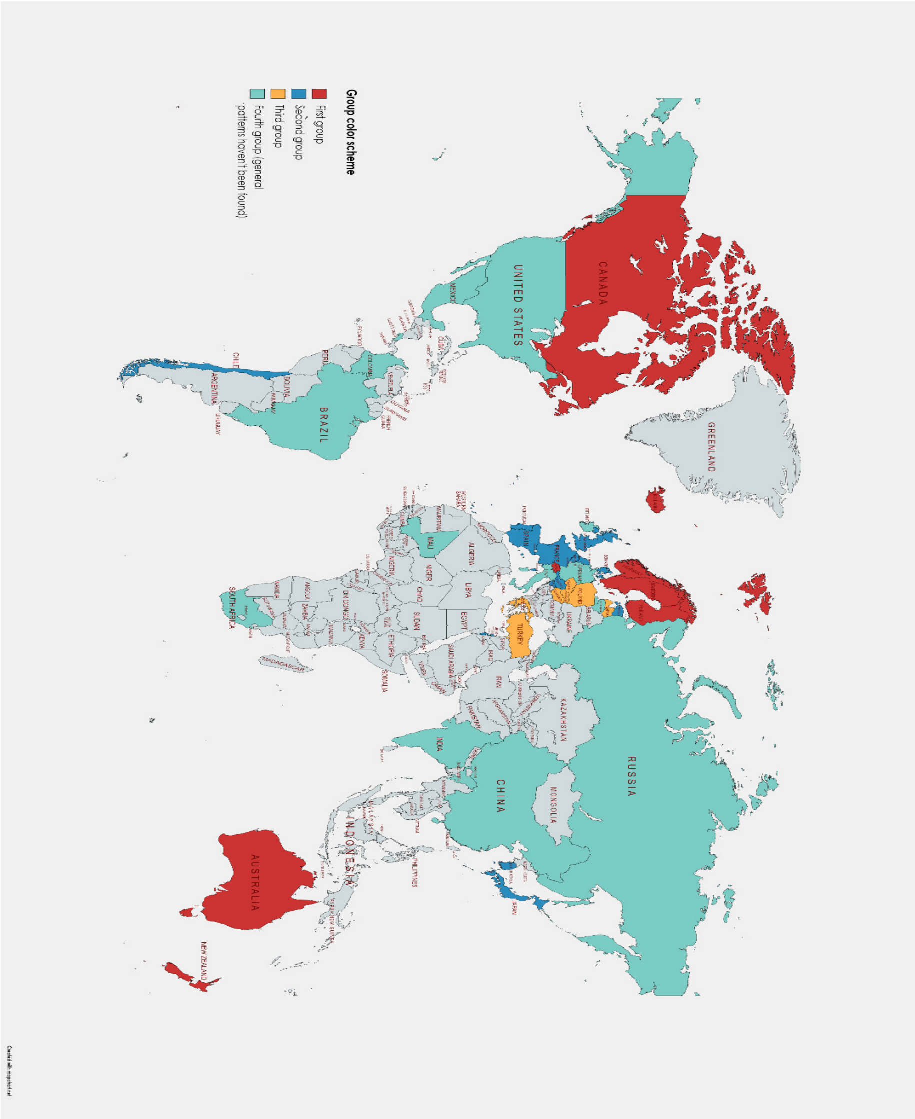

Figure 2. Grouping of states in the European region with a color key

The first group is characterized by a high standard of living, since it includes countries that developed according to the so-called «Scandinavian model», as well as Austria, Canada and Australia. At the same time, the coefficient of variation for such an indicator as «GDP per capita» is 15.9%, which indicates a weak differentiation of this indicator within the group. Thus, the maximum of this indicator is USD 65,720 per person per year, and the minimum is USD 39903. The average GDP in 2016 in the first group was 26% higher than the same indicator in the second group and 77% higher relative to the third group. Regarding the fourth group, it should be noted that it includes all countries that are not included in any other group, because its indicators have no regularity, the algorithm highlights them as «noise»; they are not used in further research.

As noted above, the first group includes all countries with a Scandinavian economic model of development. This implies that at least a number of countries in this group are characterized by the following features:
- High tax burden in the sphere of personal income and consumption of goods, which are the basis for the provision of social services to households by the state at a high level.
- High level of both public and private investment in human capital (education, childcare, etc.)
- The high level of unemployment payments, as well as the leading role of workers' and employers' trade unions, which play an important role in the organization of the labor process at all levels.

As for personal taxes, this indicator includes tax revenues from individuals for the year as a percentage of GDP. It should be noted that this indicator in the first group of countries by 2016 is 44% higher than in the second group, 147% higher than in the third group.

At the same time, high personal taxes are observed not only in the Scandinavian countries. This indicator reaches its minimum in Switzerland, where it is equal to 8.6% of annual GDP, its closest neighbor Norway has already a value of 10.7%, and the maximum value is observed in Iceland and reaches 13.6% of annual GDP.

An important feature of the group under study is the low anthropogenic load on human, which is described by the indicator «effect of atmospheric pollution». It is important to note that almost all countries in the first group have a low population density. The only country with a high population density in this group is Switzerland, which ranks 47th among all countries in the world in terms of population density, with an indicator of 185 people per square kilometer. In the rest countries of the group, population densities range from 2.8 to Australia to 20.1 in Sweden, with an average (excluding Switzerland) of 10.7 people per sq.km. and 32.51 if Switzerland is taken into account. It is assumed that the low population density predetermines the low effect of atmospheric pollution.

In general, we can say that the countries of this group belong practically to the «gold standard» of this distribution, since they have a high standard of living and a low level of anthropogenic load on a human (low effect from atmospheric pollution from causes associated with anthropogenic pollution).

In the context of living standards, the countries in the second group are not much inferior to their neighbors in the first group in terms of GDP per capita. However, at the same time, the higher level of energy consumption and the effect of atmospheric pollution indicate a greater anthropogenic load in these countries. The reasons for the increase in the effect of atmospheric pollution are due to the developed machine-building and manufacturing sectors of the economy of the studied countries and the higher population density in this group, in comparison with other groups.

Thus, the Western European region is the second in the world in terms of industrial equipment production; in 2016 the total export of equipment by the countries of the Western European region of Europe amounted to 530 billion US dollars. Based on a Report by Euromonitor International (https://www.euromonitor.com), the compound annual growth rate (CAGR) of the Western European equipment market will be 0.7% from 2016 to 2025. This applies to countries such as Austria and the Netherlands, which are among the leaders in the expected growth of this market sector. The energy-intensive production of industrial equipment has a high added value, which determines the high level of GDP of the countries and, accordingly, the indicator of the effect of atmospheric pollution, whose minimum value in the second group is 242.5 deaths per 1 million populations, while in the first group the maximum value reaches 234.

The countries of this group are characterized by stable, strong economies, which are relatively easy to cope with world economic crises.

Despite the fall in real GDP growth in 2020, the countries of the second group are expected to grow by an average of 4.2% in 2021 (https://www.euromonitor.com).

Regarding the second reason for the increase in the effect of atmospheric pollution - population density, it should be noted that the average for the countries in the second group is 198.3 people per sq.km.. and ranges from 28.5 in Estonia to 494 in the Republic of Korea.

The third group is represented by the countries of Eastern Europe and the Mediterranean, such as Greece and Turkey. It is important to note that most of the countries in this group, such as the Czech Republic, Poland, Slovakia, Hungary, Lithuania, joined the European Union in 2004. According to the Report of the European Commission of 2020 «The Role of Central & Eastern Europe in Global Value Chains: Evidence from Occupation - Level Employment Data» (https://ec.europa.eu), in general, a single model of economic development, based on a combination of highly skilled labor and low wages (according to Western European countries) can be applied to the countries of Eastern Europe. This combination has become economically attractive for investment during the period of European integration. The growth of living standards is gradually leveling this competitive advantage, and the states of this group are already facing the question of the need to create new competitive advantages. In terms of anthropogenic load, it is worth noting that this group is similar to the second group in terms of disincentives such as energy consumption and greenhouse gas emissions, but the low standard of living accounts for the fact that this group has the highest effect of atmospheric pollution - an average of 550 deaths per 1 million population with a maximum of 640 and a minimum of 459 deaths per 1 million population. At the same time, the average population density of countries in this group is 99.4 people per sq.km., with a range from 44 in Lithuania to 129 in the Czech Republic.

4. Conclusion

1. Using the DBSCAN algorithm, among the countries that were used in our sample, we can distinguish 3 groups of countries that are similar in their parameters.

2. In addition to the parameters identified at the beginning of the study, the population density indicator has a similar value for the countries of each group.

3. It has been suggested that a low level of anthropogenic impact on humans can be achieved due to two factors:

- low population density
- high standard of living (GDP per capita).

In the first case, the decrease in mortality is due to the fact that part of the population lives in areas far from industrial facilities and urbanized areas, and as a result experiences a very low level of anthropogenic pressure compared to the population of densely populated territories.

In the second case, the growth of the GDP level can offset the high population density, as in the case of some countries from the second group. In general, the Pearson's correlation coefficient between GDP per capita in the state and the effect of air pollution is -0.96, which indicates a strong inverse relationship. Based on this, the following assumption can be made: an increase in GDP entails the modernization of production, an increase in the level of living values of the population and, as a consequence, the greening of the economy.

In this case, it can be assumed that there is a certain level of economic development, after which the ecologization processes begin, and the desire of society for sustainable development begins to manifest itself more and more. Presumably, this level is approximately at the level of the indicators of the third group. The following arguments can be given in favor of this:

- if the ecologization processes begin immediately after reaching a certain level of economic development, then the difference in the level of anthropogenic load between the second and third group of countries, taking into account the similar population density, is due to the fact that the countries of the third group have not yet passed this stage of development. Consequently, the level of economic development preceding the onset of ecologization is between the boundary indicators of the third and second groups, or within the second group, since it includes both countries with a high GDP and countries with a low population density.

- if the process of greening has some time lag, then it can be assumed that the countries of the third group in the future will begin an active process of greening the economy.

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