The study of relationship in a hierarchical structure of EU sustainable development indicators

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Abstract:

Until recently, the sustainable development indicators published by Eurostat were divided into 10 thematic areas. Currently apart of this division, the new indicators system divided into 17 objectives of the Sustainable Development Strategy according The 2030 Agenda for Sustainable Development has been published. The analyses presented in this paper are concentrated on the previous system of division of sustainable development indicators. The indicators in this database are divided into 3 levels reflecting their hierarchy: headline, operational and explanatory level of indicators. The purpose of the paper is a comparative analysis of relationship between the results achieved by individual EU Member States based on hierarchical structure of indicators published by Eurostat. Such a way of analysing sustainable development indicators has not been yet practiced in the literature in this field. The value added of the paper to the current state of knowledge in this field is the opportunity not only to determine, for example, the position occupied by individual Member States within individual areas of sustainable development monitored by Eurostat, but also to analyse interrelationships occurring within particular levels of monitoring of the Sustainable Development Strategy. According to the results of the research, differences in the ranking of EU Member States on the consecutive levels of monitoring the sustainable development strategy for different areas can be observed. In line with the hierarchical method of presenting the sustainable development indicators adopted by Eurostat, state rankings were prepared for each selected indicators aggregation level. For this purpose, a taxonomic measure of development based on Weber median vector was used. The results obtained clearly present the relatively low level of correlation between the results obtained by individual EU Member States on the subsequent levels of monitoring the implementation of EU strategy. This way of hierarchical analysis can be also used in the analysis based on indicators elaborated for The 2030 Agenda for Sustainable Development.

Keywords: sustainable development indicators; European Union, Weber median vector

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1. Introduction

The concept of sustainable development which was first formulated explicitly during the Third UNEP Program in 1975 as "(…) such a course of inevitable and desirable economic development that would not materially and irreversibly affect the human environment and would not lead to the degradation of the biosphere and would not undermine the laws of nature, economics and culture" (UN, 1975), has since the beginning enjoyed considerable interest among researchers from various fields of science. The inclusion of economic issues in this definition has become the basis for formulating a broader concept of sustainable development. In the Brundtland Briefing Report of the World Commission on Environment and Development UN in 1987, sustainable development was defined as "sustainable development to meet current needs without the risk that future generations will not be able to meet their needs" (WCED, 1987).

These tendencies are confirmed by a huge increase in academic publications on the topic. In the Web of Science database alone, which contains the content of the most reputable periodicals, Zhu and Hua (2017), identified nearly 60,000 records (analysed 1987–2015) on various areas of sustainable development. As many as 149 different research areas have been identified by researchers from nearly 50 countries around the world. Most publications in this area were published by authors from the People's Republic of China (11,718), the United States (8839), the United Kingdom (4905), Australia (2976) and Germany (2958). For the sake of comparison, in 1990 only 22 studies on sustainable development were identified in the database. The increase in the number of studies and analyses in this scope is accompanied by various reflections and dilemmas which cover both the ambiguity in defining sustainable development and the freedom in constructing the methods and approaches to the measurement of the issue (Shearman, 1990, Pezzey, 1992, Goodland, 1995, Meadowcroft, 2000, Yigitcanlar, 2010, Waas et al., 2011, Schoolman et al., 2012, Pezzey and Burke, 2014). The ambiguity of the notion of sustainable development has been reflected in different definitions and interpretations thereof. At the end of 1980s, economist Pezzey (1989) identified over 60 different definitions of the term, in the following decade Michael Jacobs collected as many as 386 definitions (Jacobs, 1995) and in 2002 Caroll (2002) analysed as many as 500 different definitions that directly or indirectly referred to the term. According to the information published by Ciegis et al. (2009), approximately 100 different definitions can be found in economic literature only. The main dilemmas related to the conceptualisation of the term of sustainable development include, inter alia, doubts raised by some authors (Brown et al., 1987, Schoolman et al., 2012, Kajikawa et al., 2014, Sauve et al., 2016, Garces-Averbe and Canon-de-Francia, 2017) regarding the possibility of meeting, in practice, the basic assumption of the equivalence of all domains (economic, social and environmental) of sustainable development. It should be noted, that countries of various level of civilizational development do not pay the same amount of attention to the individual domains (areas of sustainable development). Richer countries, where the socio-economic development achieved the desired level, may pay more attention to the aspects related to the protection of natural environment, as opposed to poor countries, or even less developed ones. What is also significant, are the problems related to the identification of the destination point or the reference point (e.g. through comparison between the countries or through determination of a specific level for all countries, or different levels, depending on the current situation of individual countries) at which an economy may be considered sustainable. Yet other dilemmas are related to perceiving sustainable development as a process. In this case, in the literature (Glavic and Lukman, 2007, Berger and Zwirner, 2008) attention is drawn to the need to distinguish two issues, first: sustainability of development when e.g. the current state of the process is being researched and secondly: sustainable development where the changes in various domains of development are studied. The dilemmas related to the conceptualisation of the term are reflected, for instance, in a large number of indicators and ratios (Connelly and Graham, 2003, Parris and Kates, 2003, Haberl et al., 2004, Böhringer and Jochem, 2007, Moran et al., 2008, Palme et al., 2008, Klopp and Petretta, 2017, Liu et al., 2017, O'Brien et al., 2017, Aquilani et al., 2018) and research and analytical approaches (Hopwood et al., 2005, Duran et al., 2015, Ioppolo et al., 2016, Kharrazi et al., 2016, Moomaw et al., 2017, Arbolino et al., 2017, Becker et al., 2017) used for measurement purposes. According to the information published by the International Institute for Sustainable Development (Bossel, 1999), over 170 alternative indicators of sustainable development applied in various countries may be identified in relevant studies. The differences are visible also in the method of presenting said indicators, which cannot always be directly referred to the concept of sustainable development assuming the division into 3 areas (domains: economic, social and environmental). Such a situation pertains to indicators published by Eurostat which keeps an extended database of sustainable development indicators divided into 10 themes. In addition, indicators published in the database are divided into 3 levels reflecting their hierarchy, which may also cause difficulties in analysing these indicators (in choosing between: simultaneous analysis of all indicators on all levels or separately for each distinguished indicator aggregation level). Moreover, absence of an unambiguous determination of their nature (e.g. an indicator stimulating or impeding sustainable development) is a vital issue. This absence may result in situations wherein both high and low values of indicators may be interpreted by researchers as positive. Such a situation pertains e.g. to the indicator of generation of waste excluding major mineral waste, a high value of which will be unfavourable for the environmental area and, concurrently, difficult to mitigate for dynamically developing countries.

It have to be noted that currently, the indicators published by Eurostat are presented in two ways, taking into account: the previous breakdown into 10 thematic areas and the new indicators system divided into 17 objectives of the Sustainable Development Strategy according The 2030

Agenda for Sustainable Development (UN, 2015). Despite the new way of presenting the indicators, a significant part of them is included in the new database developed for The 2030 Agenda, which means that the results presented in this paper may be the basis for advanced analyses of new indicators.

The authors of this study are interested primarily in topics related to the measurement of sustainable development that allow comparative analysis with regard to European Union Member States on the basis of indicators published by Eurostat in the division into 10 areas. In this regard, it is a relatively new look at indicators that describe sustainable development. In the literature (Grzebyk and Stec, 2015, Antanasijevic et al., 2017), taking into account all presented indicators that are analysed as part of 10 areas isolated by Eurostat, the accomplishment of objectives included in the European Strategy for Sustainable Development is monitored the most often. Moreover, studies are available which focus particularly on the headline indicators. The available analyses are both static (the analyses are carried out separately for selected years), (e.g. Bolcarova and Kolosta, 2015) and dynamic (they research the changes in individual indicators in selected intervals), (e.g. Szopik-Dempczyńska et al., 2017). Meanwhile, the hierarchical structure of indicators raises questions regarding the relationships between the indicators on various levels (explanatory indicators, operational indicators and headline indicators).

The purpose of the study is to search for the relationship between the results achieved by individual EU Member States starting at the lowest levels of monitoring the objectives of sustainable development (explanatory indicators level), through operational indicators level up to the top level (headline indicators level). Such an approach in monitoring sustainable development indicators, in contrast to standard approaches as seen within the literature based on the analyses of a single set of indicators or several data set divided into various sub-areas, adds value to the current state of knowledge in this field and contributes to the consideration of the possibility of monitoring progress in the implementation of the Sustainable Development Strategy.

The hierarchical structure of the indicators allows to formulate questions regarding the method of achieving objectives of the European Strategy for Sustainable Development. In practice it means searching for an answer to the question whether the accomplishment of objectives of the sustainable development strategy monitored using indicators classified at the lowest level in their structure translates into results of individual EU Member States on higher indicator aggregation level. In line with the hierarchical method of presenting the sustainable development indicators adopted by Eurostat, state rankings were prepared for each selected indicator aggregation level.

For this purpose a taxonomic measure of development based on Weber median vector (Weber, 1909) was used. The analysis based on Weber median vector is a relatively well known method in the literature (Bedall and Zimmerman, 1979, Ducharme and Milasevic, 1987, Milasevic and Ducharme, 1987, Martini et al., 2002). It was applied in the socio-economic practice in such works as: (Młodak, 2006, Pulido and Sanchez-Soriano, 2009, Pechersky, 2015, Luaks and Kroupa, 2017). Research on this method was started and presented in 1909 by A. Weber, in monograph entitled “Industriaellen Standortlehre”. The first algorithm for the method was developed by J.C. Gower as late as in 1974 (Gower, 1974). An undeniable advantage of this method is, however, the possibility to eliminate distortions caused by outliers and to recognize the diagnostic qualities used at each research stage as one whole. In particular, the first advantage of the method is significant for multi-dimensional comparative analyses carried out based on data describing considerably different European countries functioning together in the European Union.

Four parts of the paper may be distinguished: the second part describes the statistical materials, including indicators description, which were utilized in the analysis. In the next one, the applied methods have been presented. The next section focuses on study results which were divided according the different levels of EU sustainable development indicators. The final part of the article puts forward conclusions and discussions. In this part the study results introduced in this paper with other analysis in the field of sustainable development have been compared.

2. Statistical Materials

The analyses presented in the paper utilize information on the indicators used to monitor the implementation of the objectives of the EU Sustainable Development Strategy (Eurostat, 2015) published by Eurostat. These Sustainable Development Indicators (SDIs) have a hierarchical structure that reflects the three levels. These indicators are used to describe 10 thematic areas (reflecting among others, 7 challenges of the Sustainable Development Strategy). The topics are gradually moving from economic, social and environmental to institutional topics and global partnerships. These areas are then divided into sub-themes that allow the presentation of operational objectives and Strategic activities. Naturally, they also reflect the main goal – that of achieving a prosperous, sustainable economy, as well as guiding principles related to good governance. At the top there are 11 so-called headline indicators. Second level (lower) represents 31 operational indicators, while the third (lowest) level includes 84 indicators describing actions that detail the indicators.1 There is also information about the so-called contextual indicators that are not used directly for measuring sustainability, but can be used as background for the research. The structure of the Sustainable Development Indicators published by Eurostat is shown in Table 1.

Table 1
The structure of the sustainable development indicators in the Eurostat database.

SD theme	Numbers of indicators:			
	headline	operational	explanatory	contextual
1. Socio-economic development	1	5	12	-
2. Sustainable consumption and production	1	3	14	2
3. Social inclusion	1	5	12	1
4. Demographic changes	1	4	3	5
5. Public health	2	2	7	-
6. Climate change and energy	2	3	7	-
7. Sustainable transport	1	4	6	1
8. Natural resources	1	4	5	-
9. Global partnership	1	3	9	1
10. Good governance	-	3	3	1

The advantage of the system of indicators used by Eurostat is their availability for all EU member states and their quality. For continuous monitoring of the quality of individual indicators, the so-called quality profiles are used. These are the metrics containing basic metadata about the indicator (definition, assessment of the level of accuracy and comparability of the indicator, as well as the level of accessibility). Eurostat collects data on a current basis from the Member States and publishes it on its website. Regularly, every two years, the European Commission report is published (based on the Eurostat report) that monitors the implementation of the EU Sustainable Development Strategy. This document presents the socio-economic situation of the EU, monitored by means of sustainable development indicators. In order to eliminate differences between countries, often the calculations of individual indicators are made by Eurostat on the basis of raw data from national statistics. Due to the quality of the indicators as provided by Eurostat, they constitute an excellent basis for monitoring real progress in achieving the objectives of the Sustainable Development Strategy by EU Member States. The proposed structure of indicators in the form of a three-stage pyramid also allows to track differences in the implementation of the assumed goals from the lowest level (illustrating actions taken for sustainable development) through operational goals, up to the highest level (monitoring the main objectives of this strategy) (Eurostat, 2015). This hierarchical layout of sustainability indicators is presented in Fig. 1.

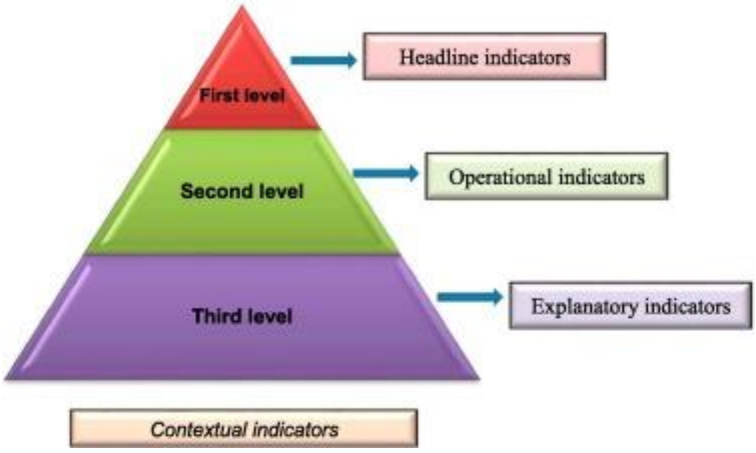

Figure 1.
The hierarchical structure of sustainable development indicators published by Eurosta

The sustainable development indicators as presented by Eurostat were used to build a database. The analyses were carried out for each of the 10 areas identified by Eurostat. Due to the purpose of the paper (to search for relationship between the results recorded by EU Member States measured at various levels of indicator hierarchy), it was necessary to accumulate indicators representing various levels of aggregations, for each of the 10 research areas separately. This purpose, however, has not been achieved for all of them. Difficulties in creating an indicator database that would be sufficient for further analyses occurred in the following areas:

• area V – public health, in the case of which only 2 indicators are used to monitor progress in sustainable development on an operational level and the data for indicator: death rate due to chronic diseases, by sex are available only dating back to 2009, and in the case of the other indicator used to measure sustainable development on that level, namely: index of production of toxic chemicals, the data are presented by toxicity class, and data for individual EU Member State are not given;

• area VIII – natural resources, for which the data for all indicators are available only for a small number of EU Member States;

• area X – good governance, for which the headline indicator has not been determined

It should also be noted that in the case of the following areas: VII – sustainable transport only one indicator allowing comparative analyses has been identified on the operational indicators level and in the case of area IX – global partnership, same applies to the explanatory indicators level. Therefore, detailed analyses have been made for the following areas: I – socio-economic development, II – sustainable consumption and production, III – social inclusion, IV – demographic changes and VI – climate change and energy. Finally, the newly built database comprises 32 indicators describing the so-called explanatory indicators level, 18 indicators describing operational indicators level and 6 indicators classified at the highest, i.e. headline indicators level. A detailed distribution of indicators by represented area of sustainable development and aggregation level has been presented in Table 2. Indicators marked with S – are stimulants whose higher values indicate a higher level of development of the analysed phenomenon. In contrast, the characteristics marked with D – are destimulants, which means that they are indicators that have the opposite effect to the stimulant, i.e. lower values are desirable.[2]

Table 2

Final set of diagnostic indicators[1].

Level	Socio-economic development
Headline	x_{1H} – real GDP per capita (S, Euro per capita)
Operational	x_{11O} – total investment (S, % of GDP) x_{12O} – young people neither in employment nor in education and training (15-24 years) - (D, % of the total population in the same age group)
Explanatory	x_{11E} – net national income (S, at current prices) x_{12E} – eco innovation index (S, % EU = 100) x_{13E} – total R&D expenditure (S, % of GDP) x_{14E} - real effective exchange rate 37 trading partners (D, % index 2005 = 100) x_{15E} – energy intensity of the economy, gross inland consumption of energy divided by GDP (D, kg of oil equivalent per 1 000 EUR) x_{16E} – total unemployment rate (D, %)
Level	**Sustainable consumption and production**
Headline	x_{2H} – resource productivity (S, Euro per kilogram)
Operational	x_{21O} – electricity consumption by households (D, 1 000 tonnes of oil equivalent) x_{22O} – organizations and sites with eco-management and audit scheme (EMAS) registration (S, number per 1000 inhabitants)
Explanatory	x_{21E} – domestic material consumption (S, 1 000 tonnes per 1000 inhabitants) x_{22E} – municipal waste generation (D, kg per capita) x_{23E} – total waste treatment (S, kg per capita) x_{24E} – total emissions of SOx (D, tonnes per 1000 inhabitants) x_{25E} – total emissions of NOx (D, tonnes per 1000 inhabitants) x_{26E} – total emissions of NMVOC (D, tonnes per 1000 inhabitants) x_{27E} – total emissions of NH3 (D, tonnes per 1000 inhabitants) x_{28E} – final energy consumption (D, 1 000 tonnes of oil equivalent) x_{29E} – motorization rate (D, cars per 1000 inhabitants) x_{30E} – area under organic farming (S, %)
Level	**Social inclusion**
Headline	x_{3H} – persons at-risk-of-poverty or social exclusion (D, percentage of total population)
Operational	x_{31O} – people at risk of poverty after social transfers (D, %) x_{32O} – severely materially deprived people (D, %) x_{33O} - people living in households with very low work intensity (D, % of total population aged less than 60) x_{34O} – early leavers from education and training (D, %) x_{35O} – tertiary educational attainment, total, age group 30-34 (S, %)
Explanatory	x_{31E} – persistent-at-risk-of-poverty rate (D, %) x_{32E} – relative median at-risk-of-poverty gap (D, %) x_{33E} - inequality of income distribution (D, % income quintile share ratio) x_{34E} – in work at-risk-of-poverty rate (D, %) x_{35E} – total long-term unemployment rate (D, %) x_{36E} – at-risk-of-poverty-rate, by highest level of education attained (D, %) x_{37E} – at most lower secondary educational attainment from 25 to 64 years (D, %) x_{38E} – total adult participation in learning (S, %) x_{39E} – low reading literacy performance of pupils (D, % - share of 15-year-old pupils who are at level 1 or below of the PISA combined reading literacy scale)
Level	**Demographic changes**
Headline	x_{4H} – employment rate of older workers (S, %)
Operational	x_{41O} – healthy life years at age 65, female (S, years) x_{42O} – healthy life years at age 65, male (S, years) x_{43O} – life expectancy at age 65, female (S, years) x_{44O} – life expectancy at age 65, male (S, years) x_{45O} – general government gross debt (D, % of GDP)
Explanatory	x_{41E} – total fertility rate (S, number of children per woman) x_{42E} – duration of working life (S, years)

Level	Climate change and energy
Headline	x_{51H} – greenhouse gas emissions (D, in CO2 equivalent, %, 1990=100%) x_{52H} - primary energy consumption (D, million tonnes of oil equivalent - TOE)
Operational	x_{51O} – greenhouse gas emissions, all sectors (D, million tonnes of CO2 equivalent) x_{52O} – energy dependence (D, %)

	x_{53O} – share of renewable energy in gross final energy consumption (S, %)
Explanatory	x_{51E} – greenhouse gas emissions intensity of energy consumption (D, %, 2010 = 100) x_{52E} – gross inland energy consumption from renewable sources (S, 1000 tonnes of oil equivalent) x_{53E} – electricity generated from renewable sources (S, % of gross electricity consumption) x_{54E} – share of renewable energy in fuel consumption of transport (S, %) x_{55E} – combined heat and power generation (S, % of gross electricity generation)

[1] where: *S – stimulants, D* – destimulants. *H* – headline indicator, *O* – operational indicator, *E* – explanatory indicator

3. Description of used mathematical methods

In the paper, to study the relationships between the results obtained by individual EU Member States, starting with the lowest level of monitoring the objectives of the Sustainable Development Strategy (explanatory indicators level), through operational indicators level up to the top level (headline indicators level), the taxonomic measure of development based on the Weber (1971) median vector was used. In the literature on economics (Młodak, 2006; Pulido and Sanchez-Soriano, 2009; Bilbao and Ordonez, 2010; Młodak, 2014; Pechersky, 2015; Luaks and Kroupa) one may encounter many different examples of the application of the taxonomic measure of development determined using the Weber median to build rankings comprising various areas of the socio-economic development of the countries of the world. This is not a new method, but the undeniable advantages related to the possibility of eliminating distortions caused by outliers should be stressed. This is of particular importance for such political and economic constructs as the European Union, which is made of considerably different European countries.

The Weber median is a multi-dimensional generalization of the classical notion of the median. It is about vector that minimizes the sum of Euclidean distance (Euclidean distance) of the data points representing the considered objects, and therefore is somehow “in the middle” of them, but it is also immune to the presence of outliers (Weber, 1971).The positional option of the linear object assignment takes a different standardization formula, compared to the classical approach, based on a quotient of the feature value deviation from the proper coordinate of the Weber median and a weighed absolute median deviation, using the Weber median (Weber, 1971):

$$z_{ij} = \frac{x_{ij} - \theta_{0j}}{1{,}4826 \cdot m\tilde{a}d(X_j)}$$

where: $\theta_0 = (\theta_{01}, \theta_{02}, \ldots, \theta_{0m})$ is the Weber median, $m\tilde{a}d(X_j)$ is the absolute median deviation, in which the distance from the features to the Weber vector is measured[1] i.e.: $m\tilde{a}d(X_j) = \underset{i=1,2,\ldots,n}{\text{med}} \left| x_{ij} - \theta_{0j} \right| \quad (j = 1,2,\ldots m)$, med is median.

The aggregate measure is calculated with the formula:

$$\mu_i = 1 - \frac{d_i}{d_{\_}}$$

$d_{\_}$ = med(**d**)+2,5mad(**d**)

where: *d*=(*d*1, *d*2,…,*d*n) is a distance vector calculated with the formula: $d_i = \underset{j=1,2,\ldots m}{\text{med}} \left| z_{ij} - \varphi_j \right|$ $i = 1,2,\ldots,n$, $\phi_j = \underset{i=1,2,\ldots,n}{\max} z_{ij}$ or $\phi_j = \underset{i=1,2,\ldots,n}{\min} z_{ij}$ – the coordinated of the development pattern vector, which is constituted of the maximum values for stimulants and minimum for destimulants.

Value 2.5 in formula d_ is called the *resistance threshold* and it delimits the barrier of favourable values of measurements of distance between the objects from the developmental pattern. Both this value and the ratio of 1.4826 (formula no. 1) have been determined using empirical research (Weber, 1971).

[1] The Weber median was calculated in *R program: l1median* of package: *pcaPP*.

The assignment of objects with a positioning measure is the basis for a division of objects into four classes. The most commonly used grouping method in the positioning scope is called the *three medians method*. It involves indicating a median of vector coordinates $\mu = (\mu_1, \mu_2, ..., \mu_n)$, which is denoted $med(\mu)$, then dividing the population of objects into two groups ($\Omega_k = \Omega_1 \ and \ \Omega_2$): those, for which the measure values exceed the median and are higher than it. Next the indirect medians are defined as: $\mathrm{med}_k(\mu) = \underset{i:\Gamma_i \in \Omega_k}{\mathrm{med}}(\mu_i)$, where $k = 1,2.$

This way the following typological groups of objects are created[2]:

- Group I: $\mu_i > \mathrm{med}_1(\mu)$,
- Group II: $\mathrm{med}(\mu) < \mu_i \leq \mathrm{med}_1(\mu)$,
- Group III: $\mathrm{med}_2(\mu) < \mu_i \leq \mathrm{med}(\mu)$,
- Group IV: $\mu_i \leq \mathrm{med}_2(\mu)$.

The first (the best) and the second group comprise objects for which results at level higher than the group's median. Thus, these are objects demonstrating a higher development level than object classified as group three and four (the worst).

3. Results

The results of the analyses made separately for each of the analysed areas are presented in tables 3-7. They show the division into 3 levels of monitoring the sustainable development strategy. As the ordering of EU Member States on different levels of hierarchical structure of sustainable development is not identical, in addition, under each table (supplementary tables no. 3a-7a) information is provided on the conformity of EU Member States ordering in each of the analysed areas. To that end Kendall rank correlation coefficient (Kendall's tau) has been employed. High values of the coefficient mean a relatively good concordance of linear ordering of countries, despite variances in ranks held on consecutive levels in the coefficient's structure and, conversely, its low values demonstrate a lack thereof. The results that may suggest conformity of the presented classification results are highlighted in the tables.

The results of the analyses performed separately for each of the considered areas are presented in Table 3, Table 3a, Table 4, Table 4a, Table 5, Table 5a, Table 6, Table 6a, Table 7. They show the division into 3 levels of monitoring the sustainable development strategy. The tables present the results obtained for those EU countries for which the positions obtained at different levels of the hierarchical structure of sustainability indicators differed the most.

[2] Groups equinumerous are getting when the number of objects in the community is divisible by four.

Table 3.
Ranking of EU Member States in terms of the level of sustainable development in the area of socio-economic development

Country	Explanatory level		Operational level		Headline level
	Value of measure	Position/group	Value of measure	Position/group	Position/group
Austria	0.7226	8/ II	0.7605	4/ I	7/ I
Belgium	0.6324	13/ II	0.6644	9/ II	10/ II
Bulgaria	0.0539	28/ IV	0.4006	23/ IV	28/ IV
Croatia	0.3290	20/ III	0.3652	24/ IV	26/ IV
Cyprus	0.4183	18/ III	0.1401	27/ IV	15/ III
Czech Republic	0.5389	17/ III	0.9322	1/ I	19/ III
Denmark	0.9116	1/ I	0.6351	10/ II	3/ I
Estonia	0.2661	26/ IV	0.7289	5/ I	20/ III
Finland	0.7404	6/ I	0.5820	16/ III	8/ II
France	0.7121	10/ II	0.6005	15/ III	11/ II
Germany	0.9103	2/ I	0.6666	8/ II	9/ II
Greece	0.5467	16/ III	0.0124	28/ IV	18/ III
Hungary	0.2909	25/ IV	0.6176	13/ II	24/ IV
Ireland	0.7798	3/ I	0.5305	20/ III	2/ I
Italy	0.6853	12/ II	0.1549	26/ IV	12/ II
Latvia	0.2973	23/ IV	0.6865	6/ I	23/ IV
Lithuania	0.3238	21/ III	0.5643	18/ III	22/ IV
Luxembourg	0.7308	7/ I	0.6235	12/ II	1/ I
Malta	0.4144	19/ III	0.8189	3/ I	14/ II
Netherlands	0.6881	11/ II	0.6783	7/ I	5/ I
Poland	0.2391	27/ IV	0.5579	19/ III	25/ IV
Portugal	0.6064	14/ II	0.3278	25/ IV	17/ III
Romania	0.3123	22/ IV	0.6037	14/ II	27/ IV
Slovakia	0.2973	24/ IV	0.6290	11/ II	21/ III
Slovenia	0.5894	15/ III	0.5682	17/ III	16/ III
Spain	0.7122	9/ II	0.4303	21/ III	13/ II
Sweden	0.7600	4/ I	0.8281	2/ I	4/ I
United Kingdom	0.7586	5/ I	0.4097	22/ IV	6/ I

Table 3a.
Kendall's τ correlation coefficient in the area of socio-economic development

Level	Explanatory	Operational	Headline
Explanatory	1.0000	0.0582	**0.7302**
Operational	0.0582	1.0000	0.1693
Headline	**0.7302**	0.1693	1.0000

Table 4.
Ranking of EU Member States in terms of the level of sustainable development in the area of sustainable consumption and production

Country	Explanatory level		Operational level		Headline level
	Value of measure	Position/group	Value of measure	Position/group	Position/group
Austria	0.3484	12/ II	0.960	1/ I	12/ II
Belgium	0.3303	14/ II	0.725	10/ II	7/ I
Bulgaria	0.3665	10/ II	0.692	20/ III	28/ IV
Croatia	0.5535	3/ I	0.700	17/ III	19/ III
Cyprus	0.3002	15/ III	0.936	2/ I	13/ II
Czech Republic	0.4491	7/ I	0.700	18/ III	21/ III
Denmark	0.3750	9/ II	0.761	3/ I	9/ II
Estonia	0.2362	24/ IV	0.757	4/ I	26/ IV
Finland	0.2262	25/ IV	0.671	22/ IV	17/ III
France	0.2231	26/ IV	0.350	28/ IV	5/ I
Germany	0.1900	27/ IV	0.531	26/ IV	10/ II
Greece	0.2721	17/ III	0.706	15/ III	16/ III
Hungary	0.6024	2/ I	0.707	14/ II	22/ IV
Ireland	0.3528	11/ II	0.702	16/ III	8/ II
Italy	0.2690	19/ III	0.699	19/ III	2/ I
Latvia	0.5198	4/ I	0.711	12/ II	25/ IV
Lithuania	0.2515	20/ III	0.727	9/ II	23/ IV
Luxembourg	0.0261	28/ IV	0.744	6/ I	1/ I
Malta	0.4669	6/ I	0.734	8/ II	14/ II
Netherlands	0.2458	22/ IV	0.662	23/ IV	4/ I
Poland	0.2504	21/ III	0.658	24/ IV	24/ IV
Portugal	0.3442	13/ II	0.735	7/ I	20/ III
Romania	0.6383	1/ I	0.689	21/ III	27/ IV
Slovakia	0.4315	8/ II	0.708	13/ II	18/ III
Slovenia	0.2828	16/ III	0.750	5/ I	15/ III
Spain	0.2446	23/ IV	0.721	11/ II	6/ I
Sweden	0.4700	5/ I	0.627	25/ IV	11/ II
United Kingdom	0.2721	18/ III	0.459	27/ IV	3/ I

Table 4a.
Kendall's τ correlation coefficient in the area of sustainable consumption and production

Level	Explanatory	Operational	Headline
Explanatory	1.0000	0,0635	-0.3122
Operational	0,0635	1.0000	-00529
Headline	-0.3122	-00529	1.0000

Table 5.

Ranking of EU Member States in terms of the level of sustainable development in the area of social inclusion

Country	Explanatory level		Operational level		Headline level
	Value of measure	Position/group	Value of measure	Position/group	Position/group
Austria	0.7166	11/ II	0.7845	4/ I	7/ I
Belgium	0.6911	12/ II	0.6769	12/ II	12/ II
Bulgaria	0.3792	26/ IV	0.447	25/ IV	28/ IV
Croatia	0.5208	21/ III	0.4188	26/ IV	23/ IV
Cyprus	0.5872	17/ III	0.5906	21/ III	22/ IV
Czech Republic	0.8000	4/ I	0.7834	5/ I	1/ I
Denmark	0.8712	2/ I	0.7831	6/ I	5/ I
Estonia	0.6071	16/ III	0.7612	7/ I	16/ III
Finland	0.9330	1/ I	0.7555	9/ II	4/ I
France	0.7418	7/ I	0.7954	3/ I	6/ I
Germany	0.7264	10/ II	0.6329	18/ III	11/ II
Greece	0.3888	25/ IV	0.0496	28/ IV	26/ IV
Hungary	0.6265	14/ III	0.4947	22/ IV	19/ III
Ireland	0.7369	8/ II	0.6994	11/ II	17/ III
Italy	0.4848	24/ IV	0.4828	24/ IV	21/ III
Latvia	0.5755	19/ III	0.6465	15/ III	25/ IV
Lithuania	0.5051	23/ IV	0.6247	20/ III	24/ IV
Luxembourg	0.5805	18/ III	0.8851	1/ I	9/ II
Malta	0.6087	15/ III	0.6729	13/ II	13/ II
Netherlands	0.8693	3/ I	0.755	10/ II	3/ I
Poland	0.6696	13/ II	0.6729	14/ II	14/ II
Portugal	0.5226	20/ III	0.486	23/ IV	18/ III
Romania	0.0766	28/ IV	0.3061	27/ IV	27/ IV
Slovakia	0.5124	22/IV	0.6331	17/ III	8/ II
Slovenia	0.7930	5/ I	0.7612	8/ II	10/ II
Spain	0.3251	27/ IV	0.6304	19/ III	20/ III
Sweden	0.7681	6/ I	0.8395	2/ I	2/ I
United Kingdom	0.7297	9/ II	0.6381	16/ III	15/ III

Table 5a.

Kendall's τ correlation coefficient in the area of social inclusion.

Level	Explanatory	Operational	Headline
Explanatory	1.0000	**0.5503**	**0.6402**
Operational	**0.5503**	1.0000	**0.6243**
Headline	**0.6402**	**0.6243**	1.0000

Table 6.
Ranking of EU Member States in terms of the level of sustainable development in the area of demographic changes.

Country	Explanatory level		Operational level		Headline level
	Value of measure	Position/group	Value of measure	Position/group	Position/group
Austria	0.4539	12/ II	0.4751	9/ II	19/ III
Belgium	0.3765	15/ III	0.4358	12/ II	22/ IV
Bulgaria	0.2382	22/ IV	0.2138	22/ IV	12/ II
Croatia	0.1790	25/ IV	0.0531	28/ IV	25/ IV
Cyprus	0.3157	17/ III	0.2558	21/ III	15/ III
Czech Republic	0.4276	13/ II	0.2699	20/ III	11/ II
Denmark	0.7355	3/ I	0.4715	10/ II	3/ I
Estonia	0.5394	8/ II	0.3065	18/ III	4/ I
Finland	0.6118	7/ I	0.5115	7/ I	8/ II
France	0.6686	5/ I	0.5685	4/ I	14/ II
Germany	0.5236	10/ II	0.5156	6/ I	2/ I
Greece	0.1171	27/ IV	0.3054	19/ III	28/ IV
Hungary	0.2119	24/ IV	0.0978	26/ IV	20/ III
Ireland	0.6475	6/ I	0.4929	8/ II	10/ II
Italy	0.0461	28/ IV	0.4019	13/ II	16/ III
Latvia	0.5237	9/ II	0.0960	27/ IV	9/ II
Lithuania	0.4974	11/ II	0.1576	24/ IV	7/ I
Luxembourg	0.2724	19/ III	0.7682	2/ I	26/ IV
Malta	0.2540	21/ III	0.6652	3/ I	24/ IV
Netherlands	0.7341	4/ I	0.4439	11/ II	6/ I
Poland	0.1263	26/ IV	0.3676	16/ III	21/ III
Portugal	0.3459	16/ III	0.3578	17/ III	13/ II
Romania	0.3080	18/ III	0.1209	25/ IV	23/ IV
Slovakia	0.2210	23/ IV	0.1750	23/ IV	17/ III
Slovenia	0.3803	14/ II	0.3774	15/ III	27/ IV
Spain	0.2591	20/ III	0.5219	5/ I	18/ III
Sweden	0.9276	1/ I	0.8400	1/ I	1/ I
United Kingdom	0.7579	2/ I	0.3899	14/ II	5/ I

Table 6a.
Kendall's τ correlation coefficient in the area of demographic changes.

Level	Explanatory	Operational	Headline
Explanatory	1.0000	0.2698	**0.5556**
Operational	0.2698	1.0000	0.1217
Headline	**0.5556**	0.1217	1.0000

Table 7.
Ranking of EU Member States in terms of the level of sustainable development in the area of climate change and energy.

Country	Explanatory level		Operational level		Headline level
	Value of measure	Position/group	Value of measure	Position/group	Position/group
Austria	0.4176	7/ I	0.5826	13/ II	19/ III
Belgium	0.2529	11/ II	0.3815	17/ III	17/ III
Bulgaria	0.1509	20/ III	0.7748	4/ I	6/ I
Croatia	0.1228	24/ IV	0.6711	7/ I	8/ II
Cyprus	0.0372	28/ III	0.2738	22/ IV	23/ IV
Czech Republic	0.2086	15/ III	0.6027	11/ II	10/ II
Denmark	0.5268	3/ I	0.8477	2/ I	9/ II
Estonia	0.1821	19/ III	0.9511	1/ I	3/ I
Finland	0.5218	4/ I	0.7085	5/ I	13/ II
France	0.2836	10/ II	0.2272	25/ IV	27/ IV
Germany	0.4991	5/ I	0.2152	26/ IV	28/ IV
Greece	0.0840	27/ IV	0.4829	14/ I	16/ III
Hungary	0.2015	16/ III	0.63	10/ II	7/ I
Ireland	0.1912	17/ III	0.3461	19/ III	18/ III
Italy	0.4349	6/ I	0.2731	23/ IV	24/ IV
Latvia	0.5856	2/ I	0.6745	6/ I	2/ I
Lithuania	0.3068	9/ II	0.4389	16/ III	1/ I
Luxembourg	0.1912	18/ III	0.2882	20/ III	11/ II
Malta	0.1080	25/ IV	0.277	21/ III	14/ II
Netherlands	0.2512	12/ II	0.3575	18/ III	20/ III
Poland	0.2337	13/ II	0.1593	27/ IV	22/ IV
Portugal	0.2328	14/ II	0.4828	15/ III	21/ III
Romania	0.1449	21/ III	0.6373	9/ II	5/ I
Slovakia	0.3979	8/ II	0.5874	12/ II	4/ I
Slovenia	0.1303	23/ IV	0.6678	8/ II	12/ II
Spain	0.1353	22/ IV	0.2472	24/ IV	26/ IV
Sweden	0.7889	1/ I	0.8322	3/ I	15/ III
United Kingdom	0.1063	26/ IV	0.0874	28/ IV	25/ IV

Table 7a.
Kendall's τ correlation coefficient in the area of climate change and energy.

Level	Explanatory	Operational	Headline
Explanatory	1.0000	0.1429	0.0370
Operational	0.1429	1.0000	**0.5561**
Headline	0.0370	**0.5561**	1.0000

As the ordering of EU Member States on different levels of hierarchical structure of sustainable development is not identical, in addition, under each table (Supplementary Tables 3a–7a) information is provided on the conformity of EU Member States ordering in each of the analysed areas. To that end Kendall's correlation coefficient (Kendall's tau) has been employed. High values of the coefficient mean a relatively good concordance of linear ordering of countries, despite variances in ranks held on consecutive levels in the coefficient's structure and, conversely, its low values demonstrate a lack thereof. The results that may suggest conformity of the presented classification results are highlighted in the tables. A detailed analysis of the results presented in the tables above shows that there is a little correlation between the results obtained at individual levels of monitoring the sustainable development strategy almost for each selected area. Similar results of the classification of EU Member States obtained between the subsequent levels (explanatory and operational levels and operational and headline levels) of monitoring the sustainable development strategy are recorded for the area of social inclusion only. The similarity of ranking results between the lowest explanatory level and the top headline level occurs also for the area of: socio-economic development and demographic changes. For two areas only: social inclusion and climate change and energy, the results of classification of EU Member States at the operational and headline levels are also similar. Total discordance between the results obtained at individual levels of monitoring the sustainable development strategy occurs in the area of sustainable consumption and production.

It should be, however, noted that in only one of the above cases did the Kendall correlation coefficient exceed 0.7 (socio-economic development, between the explanatory and headline level of indicators). This level of the Kendall correlation coefficient corresponds to the average (moderate) concordance of ranking results.

Similar conclusions may be drawn by analysing the assignment of EU Member States to individual typological groups. However also in this case the results obtained by EU countries are considerably varied. Concordance between the results obtained on consecutive levels of monitoring the objectives of the sustainable development strategy may be recorded only for the area of socio-economic development. The concordance of results obtained pertains both to the results gained at the explanatory and operational levels and to those obtained at the operational and headline levels. This means the classification to similar typological groups at the subsequent levels of monitoring the sustainable development strategy.

Sometimes, even one diagnostic feature (in this case: SD indicator) was decisive for belonging to a particular group, the level of which clearly distinguished countries themselves. Due to this, it was decided to determine the measures that can be interpreted as the scales defining the relative importance of individual diagnostic features6. These measures were calculated according to the formula (Nowak, 1990):

$$\omega_j = \frac{V_j}{\sum_{j=1}^{m} V_j} \cdot 100\%,$$

where: Vj - classic coefficient of variation calculated for the j-th diagnostic feature.

It turned out that in the first analysed area of socio-economic development on the explanatory level the most important is only one indicator (x11E – net national income at current prices). This feature was characterised by the highest variability in the set of features accepted for the study in this area. Its share exceeded 41% of the total value of the sum of variability coefficients and therefore it had a significant influence on the classification of objects (EU Member States) at this level of indicators. However, at the higher level in the hierarchical structure of indicators (operational level) in this area, the impact on the classification of EU Member States to typological groups had the feature of describing the participation of young people (15–24 years) in neither education nor training in the same age group (x12O). The share of this feature exceeded 69% of the total value of the sum of coefficients of variation. In order to show the differences in the level of the above mentioned features, average values for typological groups were calculated in individual groups and presented in Fig. 2, Fig. 3.

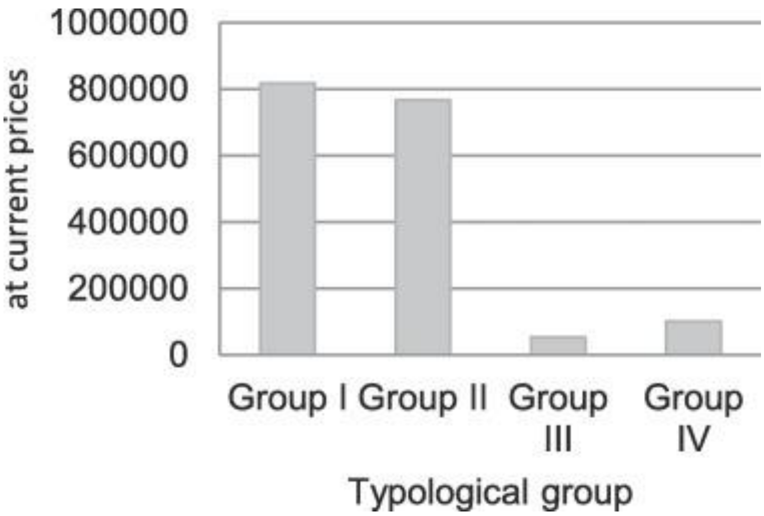

Fig. 2.

The mean values for net national income at current prices. (Operational level – the area of socio-economic development.)

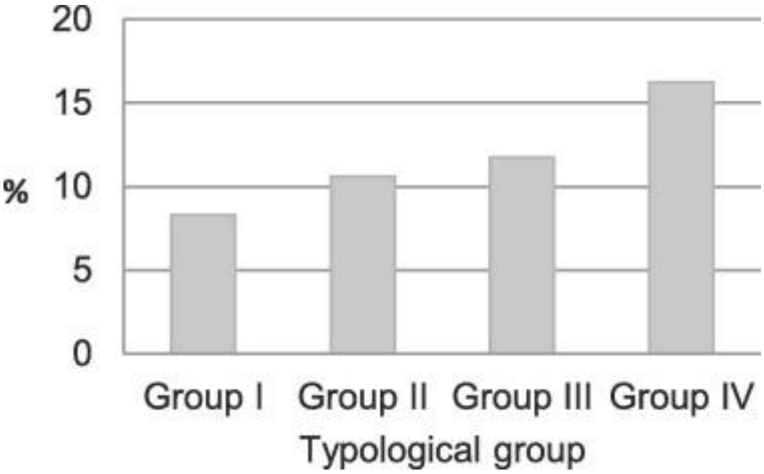

Fig. 3.

The mean value for young people (15–24 years) neither in employment nor in education and training. (Explanatory level – the area of socio-economic development.)

Within the secondly analysed areas (sustainable consumption and production), the following has been identified in a similar way: x28E – final energy consumption (26.38%). On the other hand, at the higher level (operational level), both features adopted in the study have similarly influenced the classification of EU Member States to typological groups (i.e. x21O – electricity consumption by households, 49.38% and x22O – organizations and sites with eco-management and audit scheme (EMAS) registration per 1000 inhabitants, 50.62%).

In the next analysed area (social inclusion), the features that had the greatest impact on the division of the surveyed countries into typological groups were: on the explanatory level total long-term unemployment rate (x35E – 18.30%) and total adult participation in learning (x38E – 17.48%). At the higher level, two features were also identified: severely materially deprived people (x32O – 38.73%) and early leavers from education and training (x34O – 22.77%). The average values of these attributes on both levels of the analysis of indicators are presented in Fig. 4, Fig. 5, Fig. 6, Fig. 7.

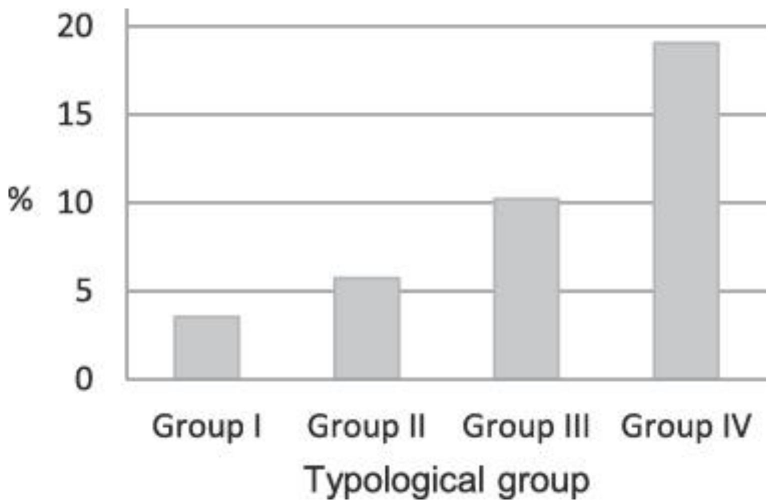

Fig. 4.

The mean value for severely materially deprived people. (Operational level – the area of social inclusion.)

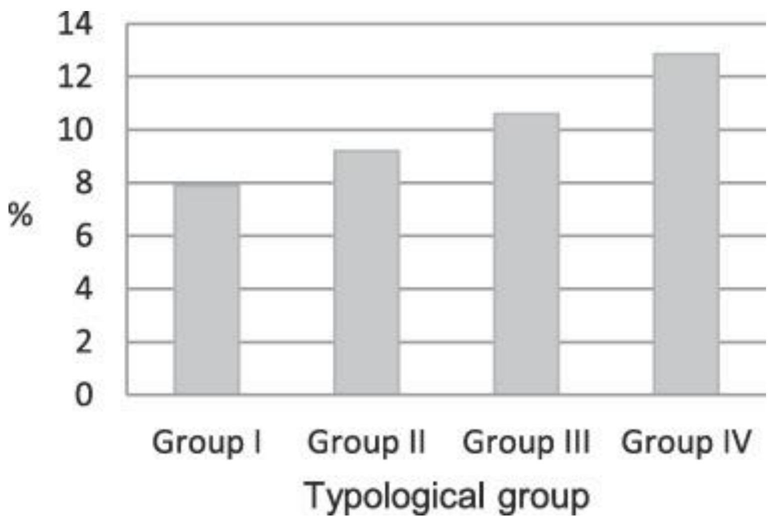

Fig. 5.

The mean value for early leavers from education and training. (Operational level – the area of social inclusion.)

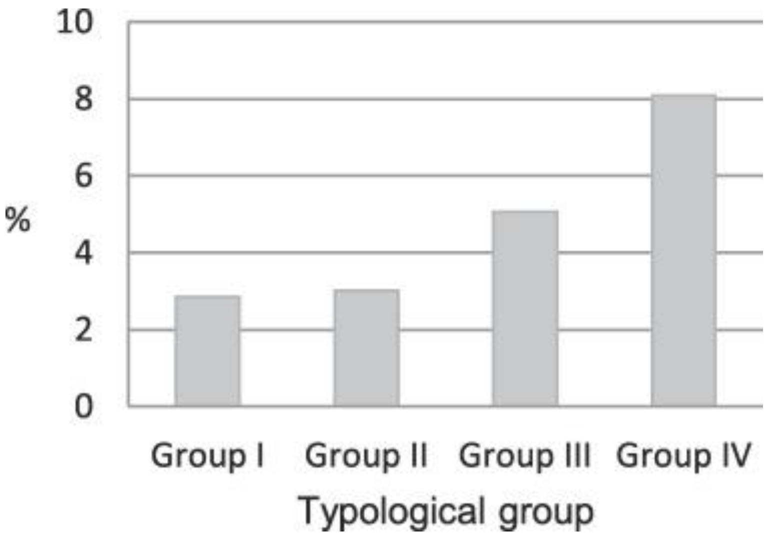

Fig. 6.
The mean value for total long-term unemployment rate. (Explanatory level – the area of social inclusion.)

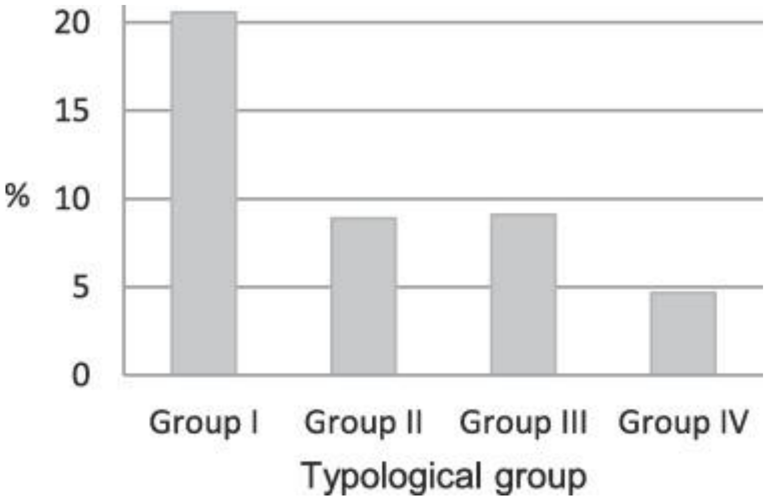

Fig. 7.
The mean value for total adult participation in learning. (Explanatory level – the area of social inclusion.)

While in the area of demographic changes the following features were identified: a) on the explanatory level: total fertility rate (x41E – 61.42%) and b) on the operational level: general government gross debt (x46O – 32.97%). In particular, the share of this first feature in explaining the assignment of the EU countries to typological groups is significant. A similar situation applies to the final analysed areas (climate change and energy). In this area at the lowest level in the hierarchical structure of indicators, the following two features had the greatest impact on the division of EU countries into typological groups: gross inland energy consumption from renewable sources (x52E – 32.65%) and combined heat and power generation (x55E – 26.80%). At the operational level, on the other hand, it was a feature describing greenhouse gas emissions (x51H – 56.30%).

The results obtained clearly show very often, the absence of relationship between the results obtained by individual EU Member States on the subsequent levels of monitoring the implementation of EU strategy. This means, e.g. that high results of classification of the EU Member States on the lowest strategy monitoring level are not reflected in the results obtained by these states on further monitoring levels. Only for 3 out of 5 analysed areas may we identify some concordance of results obtained at the lowest and highest levels of monitoring the sustainable development strategy, namely: socio-economic development, social inclusion and demographic changes (highest – over 0.7, in the area of socio-economic development). It would seem that the hierarchical arrangement of the sustainable development indicators is based on an assumption according to which the countries ranking high in terms of objectives monitored at the lowest, explanatory level, should also achieve similar results when it comes to further strategy monitoring levels. The results included herein do not confirm such a concordance. To the contrary, in the case of sustainable consumption and production, one can observe even total absence of concordance between the results of EU Member States on subsequent levels of monitoring the sustainable development strategy.

4. Discussion and conclusion

The analysis of results obtained inclines the authors to pose a question regarding the reasons for such considerable differences in the rankings of EU Member States on the consecutive levels of monitoring the sustainable development strategy for different areas of development. The search for an answer to the question will be started with the analysis of the sustainable consumption and production area, in the case of which one can notice total absence of concordance of results of classification obtained on subsequent levels of monitoring the EU sustainable development strategy. To classify EU Member States in this area, 10 indicators on the explanatory level, 2 indicators on the operational level and 1 on the highest headline level have been used. The indicators monitoring this area of research on the lowest level include mainly destimulants (7 out of 10 indicators) which describe the emission of various pollutants (4 indicators) or waste generation and waste treatment (2 indicators). In addition, also the motorisation rate and final energy consumption indicator has been included in the set of destimulants. It should, however, be stressed that the motorisation rate may also be classified as a stimulant, e.g. for developing countries, in the case of which increase in the motorisation rate is a natural consequence of socio-economic development. The final energy consumption indicator may be similarly interpreted, as well as the waste generation indicator. These indicators usually are lower for less developed countries (which is a favourable thing for destimulants). The most developed EU countries have been classified to the worst (IV) group: France, Germany, Luxembourg, Finland and Netherlands, and the less developed EU countries to the best (I) group, e.g.: Romania, Latvia, Hungary and Croatia. In addition; Sweden has been classified to the latter group. In many sources (e.g. Broberg et al., 2010, OECD, 2014, EU, 2017) this country is referred to as one of the European leaders in environmental protection.

On the next level 2 indicators are analysed, and at that the indicator describing the number of organizations and sites with eco-management and audit scheme (EMAS) registration more frequently assumes higher values for more developed countries and the indicator of electricity consumption by households, which is a destimulant, is usually lower for less developed countries. At this stage the results may be considerably different and as the ranking shows, quite independent from the socio-economic development of the country. On the other hand, only one indicator, describing resource productivity is analysed on the highest level, its higher value (desired values) are usually typical of the most developed EU countries. In the case of this area, it is difficult to expect a concordance of ranking of EU Member States recorded on further levels in indicator structure.

A moderate level of ranking concordance between operational and headline level in the sustainable development indicator structure was obtained for the area of climate change and energy. In this paper, this area is monitored by 10 indicators (5 on the explanatory level, 3 on the next operational level and 2 on the headline level). All indicators monitoring this area are similar in nature. These are indicators that describe, e.g. energy consumption, energy dependency, greenhouse gas emissions. In the case of this area, similarly as for sustainable consumption and production and in line with the observations of other authors (Amable, 2000, Dollar and Kraay, 2004), it can be expected that more economically developed countries will score poorer more often than less developed countries.

An opposite situation occurs when analysing the ranking results obtained for the areas of: socio-economic development, social inclusion and demographic changes. The results for these areas positively depend on the level of the socio-economic development of a specific country, which means that more developed countries will rank higher. This is also suggested by authors of other studies of sustainable development (Bogliaccini and Egan, 2017, Sochirca et al., 2017). The results of these areas demonstrate also higher concordance level at least in the case of the two analysed levels in the indicator structure.

The hierarchical structure of sustainable development indicators may suggest that the ranking results obtained on the subsequent levels should be concordant. This paper, however, shows that such a concordance may not be achieved for all analysed areas, and in some cases (i.e. in the area of resource productivity and energy) is it ever undesirable.

The quality and availability of statistical data is a limitation for the proposed method of analysing sustainable development indicators. In the case of data set published by Eurostat, these indicators are characterised by the very high availability (although it is not always possible to monitor indicators for all countries – some indicators concerning for example marine protection are published only for those countries that have access to the sea, etc.), however, their quality is monitored regularly by Eurostat. The approach proposed by the authors for monitoring sustainable development indicators requires their assignment to various levels of implementation of the strategy's objectives - from the level of activities through the level of operational objectives to the level of indicators monitoring the main objectives. In addition to monitoring the objectives at individual levels, it is also possible to search for mutual relations between them, which is an added value when compared with standard approaches used in the literature to monitor the progress in implementing the idea of sustainable development.

The analysis presented in the work is based on the composite indicators (also known as synthetic indices or performance indices) but the research results presented herein focus on relationships between these composite indicators presented in the sustainable development Eurostat database. These indicators may be used for monitoring of subsequent levels of the implementation of sustainable development strategy. This is a slightly different and new approach to the measurement of sustainable development than the one more frequently presented in the literature (Connelly and Graham, 2003, Parris and Kates, 2003, Haberl et al., 2004, Böhringer and Jochem, 2007, Moran et al., 2008, Palme et al., 2008, Carlucci et al., 2017, Klopp and Petretta, 2017, Liu et al., 2017, O'Brien et al., 2017), which focuses only on the analyses of headline indicators or every indicators in this area. Such a way of measurement allows to obtain extra knowledge of not only the level of accomplishment of individual objectives of the sustainable development strategy, but also associated with the study of relationships between the levels of these indicators. Composite indicators are popular tools for assessing the performance of different objects (e.g. countries, cities) in different area, i.e.: human development, sustainability, innovation and others. It should be noted, however, that the construction of such indicators should not be the only one purpose of their analysis.

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