Cluster Analysis of Sustainable Development Goal Indicators in the European Union

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Abstract Sustainable development (SD) is a fundamental objective of the European Union (EU) enshrined in its primary law. The EU Sustainable Development Strategy (SDS) was adopted in 2001 and subsequently, its external dimension in 2002. The EU Sustainable Development Goal (SDG) indicator set replaced the EU SDS in 2017. Selected indicators of this set were used in a cluster analysis to classify the sample of the 28 EU countries and Norway according to their performance in sustainability. In the selection of indicators, priority was given to the indicators reflecting decoupling and the indicators related to the climate and energy targets, along with the important representatives of the economic, social and institutional dimensions of SD generally. The Hierarchical Cluster Analysis (HCA) was applied to create four clusters using the indicator values in the initial year (primarily 2007) and the most recent year (predominantly 2016). The changes in the allocation to clusters also reflect the path of SD in the countries investigated.

Keywords Decoupling · European Union (EU) · Hierarchical Cluster Analysis (HCA) · Sustainable development (SD) · Sustainable Development Goals (SDGs)

1 Introduction

Since the 1980s, sustainability has emerged as a principle in opposition to unlimited growth (Gowdy 1994). Allen (1980) defined sustainable development (SD) as development that is likely to achieve lasting satisfaction of human needs and improvement of the quality of human life. The most quoted definition is that of the World Commission on Environment and Development (WCED 1987), according to which SD is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. At the essence of SD is a

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life of dignity for all within the planet's limits that reconciles economic prosperity and efficiency, peaceful societies, social inclusion and environmental responsibility. The United Nations (UN) adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) in September 2015. They have provided a new stimulus to global efforts for achieving SD. The SDGs represent a recent policy framework worldwide for issues that are crucial for the path of SD. The EU, in coordination with its member states, is committed to supporting the implementation of the 2030 Agenda. The EU's response to this Agenda is described in the 2016 European Commission's Communication (European Commission 2016).

In compliance with these definitions and features of SD and sustainability, this chapter deals with the SD and sustainability of the European Union (EU) countries along with Norway. The aim of the chapter is to form clusters from a group that includes the EU countries plus Norway using their sustainability performance measured by selected indicators included in the EU SDG indicator set. The indicators for all three pillars of SD are used, but in the center of interest are the crucial indicators reflecting decoupling and the indicators related to the climate and energy targets. The performance in sustainability is compared in the sample of 29 countries, i.e., the 28 EU countries and Norway, according to their allocation to individual clusters. The changes in assignments to clusters as well as in the indicator values also give information about the path of SD. The structure of the chapter is as follows: Section 2 contains theoretical foundations for the analysis and the literature review. Section 3 describes data and methodology used. Results of the analysis are presented in Sect. 4 and conclusions are included in Sect. 5.

2 Theoretical Foundations and Literature Review

The concept of SD can be interpreted as a balance between its pillars, i.e. the economic, social and environmental pillar. The concept is broad and still vague, but there is an emerging political consensus on the desirability of SD (Daly 1996). Accordingly, for the assessment of progress toward SD, it is important to use statistical tools (Adamišin et al. 2015). Because the crucial decoupling indicator included in the EU SDG indicator set, i.e., Resource Productivity, is also used and special attention is paid to it, the concept of decoupling needs to be defined. Decoupling is the process that is inevitable to move economies closer to SD and achieve the SD path. Therefore, decoupling is also applied in the monitoring of SD in the EU using decoupling indicators (Drastichová 2014, 2017). The concept of decoupling refers to breaking the link between two variables, often referred to as the driving force, mainly economic growth expressed in terms of GDP, and the environmental pressures, such as the use of natural resources, the generation of waste, and the emission of pollutants to the environment (OECD 2002). The purpose of decoupling indicators is to monitor the interdependence between these two different spheres and they usually measure the decoupling of the environmental pressure from the economic growth over a given period (OECD 2003).

Table 1 Themes and headline indicators of the sustainable development indicators

Theme	Headline indicator	Theme	Headline indicator
Socioeconomic development	Real GDP per capita, growth rate and totals	Climate change and energy	Greenhouse gas emissions Primary energy consumption
Sustainable consumption and production	Resource Productivity	Sustainable transport	Energy consumption of transport relative to GDP
Social inclusion	Persons at-risk-of-poverty or social exclusion	Natural resources	Common bird index
Demographic changes	Employment rate of older workers	Global partnership	Official development assistance as share of gross national income
Public health	Healthy life years and life expectancy at birth, by sex	Good governance	No headline indicator

Source: Eurostat (2018a)

A number of studies have dealt with the evaluation of SD in the EU, such as Radojičić et al. (2012), and Išljamović et al. (2015). As regards the work of Radojičić et al. (2012), the I-distance ranking method which synthesizes many indicators into one quantitative indicator is proposed. It is a metric distance in an n-dimensional space. The 27 EU member states were analyzed. As input variables, the EU Sustainable Development Indicators (SDIs) of the EU Sustainable Development Strategy (SDS), particularly 11 indicators, are used (see Table 1). The modifications in comparison to Table 1 are as follows. Instead of Primary energy consumption, the Share of renewable energy in gross final energy consumption is used. For the public health and demographic change themes, the indicators are used separately for men and women, while for the former the healthy life years indicator is used. For the socioeconomic development theme, the growth rate of real GDP is used. For Natural resources and Good governance themes, no indicators were used. According to the results, Sweden and Denmark are the two top EU countries concerning SD. Luxembourg, the Netherlands, the UK, and Cyprus follow them in performance. On the other hand, the new EU members, such as Latvia, Hungary, Estonia, Lithuania, and Slovakia remain at the bottom of the ranking.

Concerning the work of Išljamović et al. (2015), the authors proposed the I-distance method for evaluating countries' welfare and the 25 EU countries were analyzed. They used 13 variables according to the dimensions of SD: economic indicators (GDP per capita (current US$); Unemployment rate; Energy use (kg of oil equivalent per capita); Consumer price index (2005 = 100)), social indicators (Health expenditure per capita (current US$); Nurses and midwives (per 1,000 people); Physicians (per 1,000 people); Hospital beds (per 1,000 people); Health expenditure (% of GDP); ICT development level; Democracy index) and environmental indicators (Ecological Footprint (Rees 1992; Wackernagel and Rees 1996); Environmental Performance Index). Luxembourg is the best-performing country and it is followed by Austria, Sweden, the Netherlands, Germany, Finland, Denmark,

and Belgium in 2012, while in 2007 Luxembourg was the best-performing country followed by the Netherlands and Denmark. Romania is the worst-performing country in both years and the countries that preceded this country are Hungary (23rd in the ranking) and Bulgaria (24th in the ranking). Janković et al. (2016) ranked the EU-28 countries according to the achieved objectives of the SD strategies in 2013. The smaller set of the Commission on Sustainable Development (CSD) indicators (20) is observed and the statistical I-distance method was used. CSD indicators in the following themes are used: Poverty (3), Health (4), Education (3), Demographics (1), Atmosphere (2), Land (1) and Economic Development (6). Luxembourg is the best-performing country and it is followed by Sweden, Finland, the Netherlands, and Denmark. The worst-performing countries are Latvia, followed by Lithuania, Bulgaria, and Romania.

An additional sustainability assessment, based on an approach using a combination of Footprint Indicators, allowing also for the available biocapacity, with Human Development Indicators, was applied in Drastichová (2018a). The EU-28 countries, along with Norway, Switzerland, the USA, and Canada were investigated. Norway was evaluated as the best performing, i.e., the most sustainable, country, followed by Finland. A poor performance is especially shown by the USA, but also by the Benelux countries and Canada.

Three studies, which are most similar to the analysis carried out in this chapter, are described in more detail. Adamišin et al. (2015) analyzed the status and development of SD in Central and South-Eastern Europe countries via selected global indicators of sustainability. They analyzed whether changes in economic, social, environmental, and institutional areas led to changes in the similarity of particular countries during an approximately 12-year period. The authors carried out the analysis of similarity or changes in the development of long-term sustainability in the following countries: Bulgaria, the Czech Republic (CR), Greece, Hungary, Poland, Austria, Romania, Slovakia, and Slovenia. Indicators were selected to cover all three pillars of SD, i.e., the economic, environmental, and social one. The following indicators were used: GDP per capita, Resource Productivity in Euro per kg, life expectancy at birth in years, energy use in kg of oil equivalent per capita, and fossil fuel energy consumption in percentage of total (the headline indicators included in the EU SDS displayed in Table 1 prevail). The selection of indicators was made in order to evaluate long-term sustainability. As clustering method, group average (unweighted pair group) was used (the other conditions: distance type—Euclidean, scale type—standard deviation). In 2000, authors identified two, respectively, three clusters of countries. The first cluster is composed of Slovakia and Slovenia. These two countries are most similar among all the countries investigated. The CR can be included as well, although the degree of similarity with those two countries is significantly lower. The second cluster includes Romania and Hungary as the other two most similar countries, and moreover, Bulgaria and Poland. The third cluster contains Austria and Greece, although the degree of similarity between the two countries is very low. Their combined cluster is formed at a very high distance, i.e., these countries can be referred to as the uncoupled cluster countries. In 2012, few changes occurred in comparison to 2000. Grouping of the countries via

the indicators is more homogenous than before. The large cluster contains Romania and Bulgaria as the most similar countries, Hungary, Slovakia, and Poland (the latter is a little less similar country). The second cluster consists of Slovenia and the CR. The remaining two countries, Austria and Greece, do not create a separate cluster as it was in 2000. In 2012, Austria is closer to the group including Slovenia and the CR than to Greece in 2000. Assessments of changes over time were carried out only by comparing the individual results of each period.

Huttmanová (2016) aimed for an evaluation of the management of SD in the 28 EU countries via selected indicators characterizing SD and its main dimensions. For the evaluation based on cluster analysis, nine headline indicators of the EU SDIs representing their themes were chosen (see Table 1), while in comparison to Table 1 some modifications were used. The indicators for the Public health theme were used separately for men and women. For the Climate change and energy theme only, the Primary energy consumption indicator was used. For the Sustainable transport theme, two indicators were used: Energy consumption of transport relative to GDP and Greenhouse gas emissions by transport mode. For the Global partnership theme the indicator of CO_2 emissions per inhabitant in the EU and in developing countries was used. The Demographic Changes, Natural Resources and Good Governance themes were not reflected. A HCA method was applied and for the measurement of distance among individual points, Euclidean distance and the method of the nearest neighbor were used. Two relatively separate clusters were created. Cluster 1 is composed of Germany, France, Italy, the UK, and Spain. Cluster 2 is composed of the remaining countries, which also create other separated clusters: (2a) Belgium, Austria, Sweden, Denmark, Ireland, Finland, and the Netherlands; (2b) Bulgaria, Estonia, Croatia, Lithuania, Slovakia, Latvia, Cyprus, Malta, Slovenia, Hungary, the CR, Greece, and Portugal; (2c) Poland; and (2d) Luxembourg. It was not possible to assign Poland and Luxembourg definitely to any of the clusters. As regards the second cluster, the closest linkage, i.e., the highest measure of similarity, is shown by: (1) Croatia, Lithuania, and Slovakia; (2) Denmark and Ireland; and (3) Greece and Portugal.

Allievi et al. (2011) applied an HCA to cluster the EU-27 countries using their performance measured by the EU SDIs. The grouping of the countries is carried out by applying the HCA to selected indicators. The cluster analysis was carried out on the normalized distance matrices of the indicators due to the various natures of the included indicators. The city block distance was applied to calculate the distances of each indicator. The countries were scored according to their sustainability performance measured by the selected indicators. The weight reflects the relative importance of the indicator with respect to the other indicators in the same dimension, and it also determines the maximum scoring points available from that indicator. For each indicator, the best-performing country is assigned the number of points equal to the weight of the indicator, while the worst-performing country is given a score of zero. The remaining countries obtained a linearly scaled score according to their relative performance in relation to the best-performing country. Allievi et al. (2011) produced the results of the hierarchical agglomerative clustering carried out on the EU-27 countries for the three dimensions of sustainability in 1997 and 2005. In the

social dimension, Cyprus was the best-performing country in 1997 and Sweden in 2005 (Cyprus was the fourth best-performing country), while the worst performance was shown by Hungary in 1997 and Portugal in 2005. In the environmental dimension, Latvia had the highest performance in both years, Luxembourg the lowest performance in 1997 (that of Cyprus was the second lowest) and Cyprus in 2005 (that of Luxembourg was the second lowest). In the economic dimension, the UK followed by Denmark were the best-performing countries in 1997 and Denmark followed by Sweden in 2005. Bulgaria was the worst-performing country in 1997 and Malta in 2005. In both years, they are followed by Italy and Greece (in a different order). It can be seen that although Cyprus had a high performance for the social pillar of SD, its performance in the environmental pillar was very low. Based on the strong sustainability principle, one dimension cannot be offset by the others to achieve the path of SD. Conversely, Sweden had a high performance in all three dimensions.

The literature review and the indicators and results of the studies introduced can be used for comparisons with the sustainability assessment carried out in this chapter. In the analysis of this chapter the focus is on the simultaneous assessment of all three dimensions of SD, along with the fourth, the institutional dimension. The innovation of this chapter is the application of the new EU SDG indicator set for comparisons of the performance in sustainability and the path toward SD of the EU-28 countries along with Norway. Moreover, the selection of indicators was considered carefully to reflect all four pillars of SD and to involve the indicators that are, besides reflecting the previous EU SDIs set, also included in the other EU strategies and indicator sets focused on SD, especially the Europe 2020 strategy and the Resource Efficiency Scoreboard. It was also aimed to assess all four dimensions simultaneously in order to refer to overall sustainability and the path of SD. The changes in the composition of the clusters and between the years are also analyzed to discover if the path of SD was pursued. Moreover, two crucial indicators related to the environmental pillar in general and climate–energy aspects and decoupling in particular are analyzed more in detail to derive additional results related to SD.

3 Data and Methods Applied

3.1 Cluster Analysis

Cluster analysis is a convenient method for identifying homogenous groups of objects called clusters. These objects (or cases, observations) in a specific cluster share many characteristics, but are very dissimilar to objects not belonging to selected cluster (Mooi and Sarstedt 2011). HCA of n objects is defined by a stepwise algorithm that merges two objects at each step, the two which have the least dissimilarity or distance. The classification contains a series of partitions of the data where the first consists of n single-members clusters, while the last is made by a single group containing all n individuals. At each step, individuals or groups of

Table 2 Indicators chosen for the cluster analysis and the data modifications

SDG/indicators used	Initial year	Recent year
SDG1: People at risk of poverty or social exclusion; percentage	HR—2010	–
SDG7: Population unable to keep home adequately warm (% of population)	HR—2010	–
SDG9: Gross domestic expenditure on R&D, all sectors (% of GDP)	–	FR—2015
SDG10: Gini coefficient of equalized disposable income (coefficient of 0 (maximal equality) to 100 (maximal inequality))	HR—2010	
SDG11: Recycling rate of municipal waste (% of total waste generated)	–	IR, PT—2014; SL—2015;
SDG12: Resource Productivity, PPS per kilogram		NO—2015
SDG13R: Share of renewable energy in gross final energy consumption (%)	–	–
SDG16: Corruption perceptions index (score scale of 0 (highly corrupt) to 100 (very clean))	–	–
SDG17: Shares of environmental taxes in total tax revenues (% of total taxes)	–	–

SDG2: Area under organic farming (% of utilized agricultural area); SDG3: Life expectancy at birth total (years); SDG4: Early leavers from education and training total (% of population aged 18–24); SDG5: Gender employment gap (percentage points (p.p.); SDG8G: Real GDP per capita, chain linked volumes (percent. change on previous period); SDG8U: Long-term unemployment rate; SDG13G: Greenhouse gas emissions—tones per capita; SDG13GI: Greenhouse gas emissions intensity of energy consumption.
Source: Eurostat (2018a); author's elaboration

individuals which are closest are fused together (Everitt 1993). An HCA was used to form clusters of countries investigated based on the indicator values of 2 years: the most recent year, predominantly 2016, and the initial year 2007. The data are not available in some countries and for several indicators in these years and therefore, some modifications were used (described in Table 2). Ward's method is applied as a cluster method and the squared Euclidean distance was chosen from measures for interval to specify distance. The reason is that quantitative variables are applied. The Z scores were chosen from the available standardization methods since the variables included are measured in different units (Aldenderfer and Blashfield 1984; Meloun and Militký 2002; Řezanková et al. 2007).

3.2 Sets of Indicators Applied in the Cluster Analysis

The former indicator set for the measurement of the progress toward the EU SDS was the EU SDIs composed of more than 130 SDIs. Ten indicators represented headline indicators. They give an overall view of the EU's progress toward SD with regard to the objectives and targets of the EU SDS. The main themes and headline indicators are displayed in Table 1.

The EU SDS and its SDI set were replaced with the EU SDG indicator set, which reflects the themes of the SDGs. Therefore, the indicators from the EU SDG indicator set were chosen for the investigation. This set contains 100 indicators that are structured along the 17 SDGs (see Eurostat 2018a). Each goal has six indicators primarily attributed to it, except for goals 14 and 17 which only have five indicators. Multipurpose indicators are included as well. Thus, although some of the indicators chosen for the analysis also represent additional SDG themes, they were selected according to the criteria to reflect all the relevant aspects of SD and the indicators included in the EU's priorities and its relevant strategies were favored. All indicators are grouped in sub-themes to show interlinkages and to emphasize different aspects of each SDG. When compared to the previously used set for the measurement of SD, the EU adjusted its framework to the global agenda and the indicators are currently classified according to the framework of 17 SDGs. However, a number of indicators remained the same or similar to those used under the framework of the EU SDIs. It means that the priority areas for SD in the EU remained similar (see more in Drastichová (2018b)). It was endeavored to choose the crucial representative indicator of each SDG, apart from SDG14 and SDG15. SDG14 is irrelevant for some countries and for SDG15 there was a lack of data in many countries.

This process of selection is specified at the beginning of Sect. 4. Nine indicators were chosen for which the data were available and which also satisfied the conditions required for a cluster analysis. The indicators left out from the analysis due to noncompliance with these conditions are also summarized in the last row of Table 2.

The process of indicator selection was determined by their relevance as representative indicators of the SD pillars. The indicators used as headline indicators of the EU SDIs (SDG1, 3, 8G, 12, and 13G) (Eurostat 2018a) and the Europe 2020 strategy (SDG1, 4, 9, 13G, and 13R) (European Commission 2010), along with the Resource Efficiency Scoreboard indicators (SDG2, 12, 13G, 13R, 11, and 17) (Eurostat 2018b), were favored.

The priority was to reflect all three basic dimensions of SD, along with the aspects of decoupling (see more in Drastichová (2016, 2017)) represented by the SDG12 indicator that is also the headline indicator in theme 2 of the EU SDIs (see Table 1) and the lead indicator in the Resource Efficiency Scoreboard, along with the institutional pillar, for which the relevant SDG16 indicator was chosen. Moreover, the SDG17 indicator is also used as the representative of the institutional aspects. Within the EU SDI set, the SDG17 indicator is the operational indicator of the Good Governance theme and its subtheme named Economic instruments. The SDG13R indicator, i.e., the Share of renewable energy in gross final energy consumption, plays a crucial role in all four indicator sets (in the EU SDIs, it is the operational indicator in the Energy subtheme). However, two other indicators related to climate change issues were omitted due to their insignificance (SDG13G and 13GI). Climate change is a crucial topic for SD. More particularly, it is the unsustainable trend and one of the main threats to SD (according to the EU SDS, see Commission of the European Communities (2001)) and it requires additional specific analyses (see more in Drastichová (2017)). Accordingly, the climate and energy topic is represented by

the SDG13R indicator that is included in all the above indicated indicator sets. Moreover, the social aspects related to energy are represented by the SDG7 indicator. The SDG8U indicator was considered to reflect the Socio-Economic Development theme and its subtheme named Employment in the EU SDI set (see more on Eurostat 2018a), while Employment is also one of the themes in the Europe 2020 strategy for which the targets and headline indicators were determined (European Commission 2010). The SDG10 indicator was chosen to underline the importance of the social pillar as some of the other crucial social indicators had to be omitted due to the noncompliance, i.e., the SDG3, 4, and 5 indicators. The SDG4 indicator was also included as the operational indicator in theme 3, named Social inclusion, in the EU SDIs (the subtheme—Education). On the other hand, the inclusion of the SDG10 indicator is the innovation of the EU SDG indicator set when compared with the EU SDIs set. Using the indicated criteria, the nine indicators included in Table 2 (apart from the last row) were chosen.

To sum up, the SDG1 and the SDG10 indicators represent the social pillar of SD, along with the SDG7 indicator, although the latter is predominantly related to energy sustainability (see Table 2). The SDG9 indicator represents the economic pillar and the SDG11, 12, 13R, and 17 indicators reflect the environmental pillar. Resource Productivity (SDG12) is also an important decoupling indicator reflecting the efficiency of resource use, and the Share of environmental taxes in total tax revenues indicator (SDG17) also reflects the institutional aspects, or partnership for the goals. The SDG16 indicator is the direct representative of the institutional pillar of SD.

4 Results of the Analysis

The results of the HCA are included and analyzed in Sect. 4.1 and the detailed analysis of the indicators is included in Sect. 4.2. The overall assessment is included in Sect. 4.3. Eurostat (2018a) was used as the data source.

4.1 Results of the Cluster Analysis

Primarily, all the 17 indicators introduced in Table 2 were chosen for the analysis. According to the results of the One-Way ANOVA, not all the indicators included were significant by forming the clusters at the 0.05 level of significance. Therefore, the SDG2, 3, 4, 5, 8G, 8U, 13G, and 13GI indicators (insignificant at the 0.05 level of significance in the initial or recent year, or both of them) were omitted. All the nine remaining indicators were significant by forming the clusters. The SDG16 indicator had the highest influence in both years because the calculated F-statistic showed the highest level (27.533 and 32.142 in the initial and the recent period, respectively). Further, the correlation and multicollinearity of the indicators included were tested. Meloun and Militký (2002) indicate that if the Variance Inflation Factor

Table 3 The composition of the four created clusters

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Initial year	BE, DE, ES, FR, LU, NL, AT, UK	BG	CZ, EE, IE, GR, HR, IT, CY, LT, LV, HU, MT, PL, PT, RO, SL, SK	DK, FI, SE, NO
Recent year	BE, DE, FR, LU, NL, AT, UK	BG, EE, GR, ES, HR, IT, CY, LT, LV, PT, RO	CZ, IE, HU MT, PL, SL, SK	DK, FI, SE, NO

Source: Author's elaboration

AT Austria; *BE* Belgium; *BG* Bulgaria; *CY* Cyprus; *CZ* Czechia, *DE* Germany; *DK* Denmark; *EE* Estonia; *ES* Spain; *FI* Finland; *FR* France; *UK* The United Kingdom; *GR* Greece; *HR* Croatia; *HU* Hungary; *IE* Ireland; *IT* Italy; *LT* Latvia; *LU* Luxembourg; *LV* Lithuania; *MT* Malta; *NL* The Netherlands; *NO* Norway; *PO* Poland; *PT* Portugal; *RO* Romania; *SE* Sweden; *SL* Slovenia; *SK* Slovakia

(VIF) is higher than 10, strong multicollinearity exists in data. The VIF statistics were below 10 in all the regressions investigated. In this group of nine indicators, the highest level of the Pearson Correlation was between SDG1 and SDG10 in the recent year (0.858) and between SDG1 and SDG7 in the initial year (0.829). The Pearson Correlation also exceeded 0.8 between SDG1 and SDG7 in the recent period (0.814) and between SDG9 and DG16 in the initial period (0.807). Thus, all the coefficients were lower than 0.9, and none of them confirmed a strong dependence, which is signified by values of 0.9 or above (Sambandam 2003) (Table 3).

The allocation of countries to clusters in both years is shown in Table 4. Cluster 1 contains the more developed EU countries, i.e., the Benelux countries, Austria, Germany, France, and the UK, plus Spain in the first year. Cluster 2 contains only Bulgaria in the first year, but all four Southern countries are included in the second year. Spain shifted from Cluster 1 and the other three countries from Cluster 3. Moreover, all three Baltic countries shifted to Cluster 2 in the recent year from Cluster 3, where they were included in the first year. This is also the case for Cyprus, Croatia, and Romania. Additional Cluster 3 countries remained in Cluster 3. No country was added to this cluster in the recent period and thus, the number of countries decreased from 16 to 7. Cluster 4 has the same composition in the initial and recent year, it is composed of the 4 Northern countries.

The characteristics of the clusters in terms of their means and standard deviations are summarized in Table 4. The following Boxplots displayed by Figs. 1 and 2 show the distribution of data for nine indicators in the four clusters based on the five-number summary including minimum, first quartile, median, third quartile, and maximum. Accordingly, the results included in Table 4 were extended.

Figures 1 and 2 show the distribution of data for nine indicators in the initial and the recent year, respectively. Accordingly, the changes in the composition of clusters 1–3 are reflected. Subsequently, the order and ranking of the clusters' means and medians are summarized in Table 5, according to which the sustainability and SD of clusters are evaluated. The performance of the clusters is assessed according to the means and medians for nine indicators in particular clusters in both periods.

Table 4 Descriptive statistics for the four clusters in the initial and the recent year

Indic (Clus)	Mean (Rec)	St. D. (Rec)	Mean (In)	St. D. (In)	Indic (Clus)	Mean (Rec)	St. D. (Rec)	Mean (In)	St. D. (In)
17(1)	5.821	1.548	6.163	1.599	17(3)	7.687	1.666	7.584	1.178
16(1)	78.143	4.880	74.625	6.255	16(3)	57.857	8.335	53.688	9.555
13R(1)	13.386	9.750	8.375	8.297	13R(3)	12.743	4.807	12.400	8.045
12(1)	2.960	0.808	2.035	0.597	12(3)	1.835	0.340	1.118	0.466
11(1)	52.086	8.293	46.200	13.147	11(3)	33.757	15.179	12.694	9.680
10(1)	28.814	2.053	28.625	2.608	10(3)	27.114	2.427	30.863	4.631
9(1)	2.243	0.661	1.859	0.421	9(3)	1.206	0.490	0.839	0.336
7(1)	3.800	1.571	5.225	4.454	7(3)	6.086	1.787	15.725	12.261
1(1)	19.329	1.845	19.425	3.050	1(3)	20.329	4.306	26.831	7.762
17(2)	8.625	1.669	10.110	–	17(4)	6.730	1.487	7.270	2.030
16(2)	53.636	8.652	41.000	–	16(4)	88.000	2.160	88.250	2.363
13R(2)	22.855	7.963	9.200	–	13R(4)	48.525	16.599	37.925	18.307
12(2)	1.646	1.053	0.560	–	12(4)	1.371	0.333	1.331	0.431
11(2)	27.891	11.072	20.600	–	11(4)	47.425	6.910	42.325	4.822
10(2)	34.082	2.286	35.300	–	10(4)	26.425	1.424	24.625	1.312
9(2)	0.891	0.334	0.430	–	9(4)	2.728	0.505	2.673	0.830
7(2)	18.818	10.960	67.400	–	7(4)	1.975	0.846	3.500	4.553
1(2)	30.582	5.338	60.700	–	1(4)	16.725	1.228	16.150	1.546

Source: author's elaboration

Indic Indicator; *Clus* cluster; *In* initial year; *Rec* recent year; *St. D.* Standard deviation

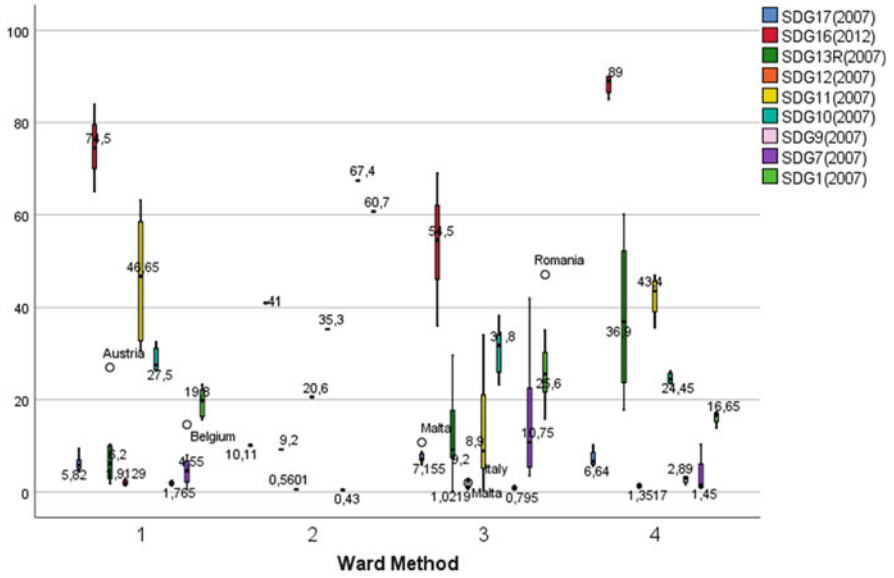

Fig. 1 Boxplots for the indicators in the initial year, classified into the four clusters (Source: Author's elaboration)

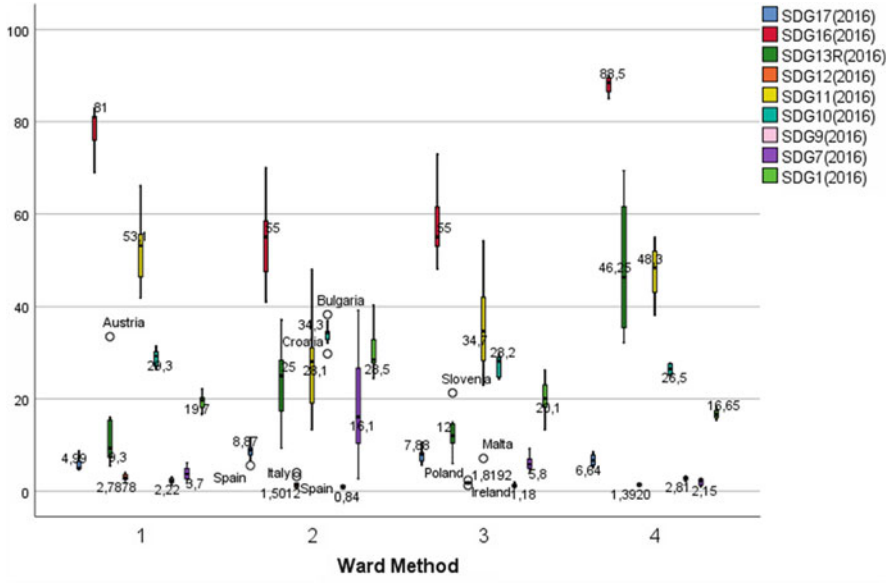

Fig. 2 Boxplots for the indicators in the recent year, classified into the four clusters (Source: Author's elaboration)

Table 5 Overall ranking of the means and medians in the individual clusters, the initial and the recent year

SDG	Clus1 Initial	Clus1 Recent	Clus2 Initial	Clus2 Recent	Clus3 Initial	Clus3 Recent	Clus4 Initial	Clus4 Recent
17	4	4	1	1	2	2	3	3
16	2	2	4	4/3	3	3/3	1	1
13R	4	3/4	3/2	2	2/3	4/3	1	1
12	1	1	4	3	3	2	2	4
11	1	1	3	4	4	3	2	2
10	3	2	1	1	2	3	4	4
9	2	2	4	4	3	3	1	1
7	3	3	1	1	2	2	4	4
1	3	3	1	1	2	2	4	4

Note 1: 1—the highest level; 2—the second highest level, 3—the third highest level, 4—the lowest level; Clus—cluster

Note 2: If the order of means and medians is different, the first in the order the mean and second in the order the median is indicated

Source: Author's elaboration

As regards the SDG1, 7, and 10 indicators, which are People at risk of poverty or social exclusion, Population unable to keep home adequately warm and Gini coefficient of equalized disposable income, respectively, the highest means and medians and thus the worst results were shown by cluster 2 in both years. For the SDG10 indicator, the order changed for clusters 1 and 3 between the initial and the recent year, i.e., cluster 3 achieved the higher performance in 2016 (see Table 5). The lowest means and medians and the best performance were achieved by cluster 4. It can be concluded that for these three crucial social indicators, while the SDG7 indicator also reflects energy (environmental) aspects, cluster 4 is the best-performing cluster and cluster 2 showed the lowest performance in both years. Although cluster 2 changed its composition significantly, its performance remained the lowest. On the other hand, the means and medians dropped significantly for the SDG1 and 7 indicators and slightly for the SDG10 indicator. For the SDG9 indicator, i.e., gross domestic expenditure on R&D, the highest means and medians, and thus the highest performance, were achieved by cluster 4 and the lowest ones by cluster 2 in both years. The results for this indicator reflecting the economic pillar of SD, together with the possibilities for decoupling and thus for improvements in the environmental dimension as well as in the other two SD dimensions, confirm the highest performance of cluster 4 and the worst results shown by cluster 2. The changes of means and medians between the years (the decreases in the case of SDGs 1, 7, and 10 and the increases in the case of SDG9) predominantly reflect the shifts toward the higher sustainability levels, except for those having taken place for both the median and the mean in cluster 4 for the SDG1 indicator, those in cluster 4 and cluster 1 for the SDG10 indicator and medians in cluster 4 for the SDG7 and SDG9 indicators. Thus, the most sustainable cluster, which was cluster 4, and the second

best performing, which was cluster 1, showed some changes toward lower sustainability levels, while cluster 4 did not even change its composition.

The recycling rate of municipal waste representing SDG11 had the highest means and medians in cluster 1 in both years. The lowest values were shown in cluster 2 in the recent and cluster 3 in the initial year. Cluster 4 is the second best-performing cluster in both years. Clusters 2 and 3 changed their order when cluster 3 increased its performance in relation to cluster 2. The highest means and medians for Resource Productivity representing SDG12 were in cluster 1 in both years. The lowest levels were shown by cluster 2 (represented only by Bulgaria) in the initial and cluster 4 in the recent year. Despite the high performance of cluster 4 in the majority of the included indicators, Resource Productivity in PPS per kilogram showed relatively low values in Finland (0.802 and 0.962 PPS per kg, respectively) and middle-sized values in other three countries. This is especially the case for the recent year because, in 2007, Norway showed relatively high Resource Productivity (higher than the average value in the sample, i.e., 1.819) and the overall performance of cluster 4 was higher. In the recent year, it is highest in Denmark (1.74 PPS per kg, which is below the average value in the sample. The highest mean average and median average for the SDG13R indicator (Share of renewable energy in gross final energy consumption), and thus the best performance, were achieved in cluster 4 in both years. The lowest values were seen in cluster 1 in the first year and in cluster 3 in the second. However, the median in cluster 1 was also the lowest in the recent period, lower than the mean and median of cluster 3 (see Fig. 2). For these three indicators, the results are contradictory to some extent. For the SDG11 and 12 indicators, the highest performance is shown by cluster 1, but this cluster showed relatively low average Share of renewable energy (SDG13R). On the other hand, cluster 4 showed the unambiguously highest performance in this indicator, the second highest performance in the SDG11 and SDG12 indicators in the initial period, but the lowest performance in the latter indicator in the recent period. For all three indicators representing the environmental dimension of SD, the means and medians increased in all clusters, which can be understood as a shift toward higher sustainability as their levels increased between the years.

For the SDG16 indicator, i.e., Corruption Perceptions Index, the highest means and medians (and the best performance) were in cluster 4 and the second highest in cluster 1 in both years. The lowest levels and the poorest performance were shown by cluster 2. However, the medians showed the same levels for clusters 2 and 3 in recent year. Finally, for the SDG17 indicator, i.e., Shares of environmental taxes in total tax revenues, the highest levels were in cluster 2 and the lowest levels in cluster 1 in both years. Some changes occurred in the order of the descriptive statistics in clusters 3 and 4. In the initial period, the mean of cluster 4 is higher than the median in cluster 3, in the recent period the opposite is true. In the last two indicators representing the institutional dimension of SD (the latter also the environmental dimension), the results are not unambiguous because cluster 2 showed one of the poorest results in the SDG16 indicator, but the highest average Shares of environmental taxes in total tax revenues (the SDG17 indicator). On average, cluster 4 can then be evaluated as the best-performing cluster, having the best results for the

SDG16 indicator; although the values of the SDG17 indicator are lower (explained in more detail in Sect. 4.2). For the SDG16 indicator, the only slight decreases in mean and median occurred in the best-performing cluster, cluster 4. As regard the SDG17 indicator, the means and medians declined in clusters 1 and 2 between the years. This is also the case for the mean in cluster 4, but its median did not change.

To sum up, cluster 4 showed the highest performance in most indicators, but changes toward higher unsustainability predominantly occurred in this cluster as well. Overall, it can be regarded as the most sustainable cluster despite some slight negative changes in the indicators of the economic, social, and institutional dimensions. On the other hand, improvement occurred in three crucial environmental indicators (the SDG11, 12, and 13R indicators), which also happened in all the clusters. Cluster 4 did not change its composition between the years and therefore the changes are good assessable. Conversely, cluster 2 changed the composition significantly and this is the cluster with the lowest average performance and sustainability. Cluster 1 can be evaluated as the second best-performing cluster. The values of the indicators in particular countries are further analyzed in Sect. 4.2 in order to explain the results of the cluster analysis in more detail.

4.2 Deeper Analysis of the Relations Between Selected Indicators

In this subsection, the focus is on the summary assessment of all the indicator values in the countries of the sample. Subsequently, the values of two important indicators representing the environmental pillar of SD, along with the climate–energy aspects and those of decoupling are evaluated according to their levels in the four clusters. As regards the values of all the indicators in the countries investigated, the five countries with the highest and lowest values for each indicator are displayed in Table 6.

The indicator of people at risk of poverty or social exclusion (SDG1) was the lowest in Sweden in 2007 (13.9%). However, it was the lowest in CR in 2016 (13.3%). The shares of the Northern countries included in cluster 4 are among the lowest in both years (all below the average levels), although the share in Sweden in 2016 is slightly higher (18.3%). The highest shares in both years are shown by Bulgaria, followed by Romania. The share of Greece is the third highest in 2016 (35.6%). While the shares decreased significantly in Bulgaria and Romania (from 60.7% in Bulgaria and 47% in Romania by 20.3 and 8.2 p.p., respectively), along with Poland (by 12.5 p. p), the share increased most in Greece (7.3 p.p.), followed by Spain (4.6 p.p.), and Sweden (4.4 p.p.). These results are related to the impacts of the economic crisis. In addition to the Northern countries and the CR, the countries with low shares in both years are the Netherlands and Austria. However, in both countries, the shares increased slightly. Population unable to keep home adequately warm (SDG7) showed the lowest levels in Norway (0.9%), followed by Luxembourg and

Table 6 Countries with the highest/lowest levels of SDG indicators in the initial and the recent year

SDG	17	16	13R	12	11	10	9	7	1
Initial (H)	MT, DK, BG, NL, CY	FI, DK, SE, NO, NL	NO, SE, FI, LT, AT	NL, LU, UK, MT, FR	DE, AT, BE, NL, SE	DK, SK, NO, SE, SL	FI, SE, DK, DE, AT	BG, PT, CY, RO, PL	BG, RO, LT, PL, HR
Recent (H)	LT, SL, GR, BG, HR	DK, FI, SE, NO, NL	NO, SE, FI, LT, AT	IT, NL, UK, LU, ES	DE, AT, FI, SL, BE	FI, CZ, NO, SL, SK	SE, AT, DE, DK, FI	BG, LV, GR, CY, PT	BG, RO, GR, LV, IT
Initial (L)	DE, SE, BE, ES, FR	HR, RO, IT, BG, GR	NL, BE, LU, UK, MT	FI, LT, EE, BG, RO	CY, LT, MT, HR, RO	RO, PT, LT, BG, GR	LT, RO, SK, BG, CY	SE, NL, FI, NO, LU	NO, LU, CZ, NL, SE
Recent (L)	SE, BE, FR, DE, LU	RO, HU, IT, GR, BG	CY, BE, NL, MT, LU	FI, EE, LT, RO, BG	HR, CY, GR, RO, MT	BG, LV, RO, LT, ES	LV, MT, CY, RO, LT	SE, NL, FI, LU, NO	NL, DK, FI, NO, CZ

Note 1: In all the fields, the countries are ordered according to the indicator values: from the highest to the lowest ones
Note 2: For countries the official country codes are used; H—highest, L—lowest
Note 3: The same abbreviations for countries as in Table 3 are used
Source: Eurostat (2018a); author's elaboration

Finland (both 1.7%), the Netherlands and Sweden (both 2.6%) and Denmark, Estonia, and Austria (all three 2.7%) in 2016. Luxembourg was the best-performing country in 2007 with its share of 0.5% of population, but it increased by 1.2 p.p. Denmark showed a relatively high share in 2007 (10.3%), but the drop was great as well (by 7.6 p.p.). The highest decline occurred in Bulgaria and Romania, while Bulgaria is still showing the highest share (39.2%). The share of Romania in 2016 is the seventh highest (13.8%) following Bulgaria, Lithuania (29.3%), Greece (29.1%), Cyprus (24.3%), Portugal (22.5%), and Italy (16.1% of population).

For SDG10, i.e., the Gini coefficient of equalized disposable income, the lower the values, the lower is the inequality achieved. In both years, Slovenia and Slovakia showed among the lowest levels: Slovenia in 2007 (23.2) and Slovakia in 2016 (24.3). Overall, all five Northern countries showed relatively low levels in both years (below the average values) that confirms the best results of cluster 4 in this indicator. However, Sweden, the second best-performing country in 2007 with a coefficient of 23.4, showed the highest increase in the overall sample (by 4.2). Currently, the three best-performing countries are the above mentioned Slovakia, followed by Slovenia (24.4), and Norway (25). The CR, Belgium, and Austria also showed low inequality in both years and the Netherlands in the recent period. The highest inequality was shown by Bulgaria in the recent and in Romania in the initial year (both: 38.3 in the

corresponding year). Romania showed the highest drop in the sample (by 3.6), but the coefficient of Bulgaria showed one of the highest increases (by 3). All four Southern countries showed high levels (above the average levels). Although those of Spain and Italy were slightly lower in the initial period (31.9 and 32, respectively), increases occurred in these countries. All the previous indicators represent the social dimension of SD, or socio-energy aspects, while the latter is the case for SDG7.

For SDG 9 represented by Gross domestic expenditure on R&D, the highest rates exceeding 3% of GDP in 2016 were achieved by Sweden (3.25%) and Austria (3.09%) and they are followed by Germany (2.94%), Denmark (2.87%), and Finland (2.75%). In Finland and Sweden, the shares decreased (from 3.35 and 3.26, respectively), but in the remaining countries they increased. Austria showed the highest increase in the overall sample, while Finland showed the highest decrease (0.67 p.p. and −0.6 p.p., respectively). In 2016, except for Slovenia, the CR, Estonia, and Hungary, the remaining new member countries showed ratios lower than 1% of GDP, while Latvia (0.44%), Romania (0.48%), and Cyprus (0.5%) showed the very lowest shares. This is evidence of the best results achieved by cluster 4 and of the poorest performance of cluster 2 in this indicator representing the economic dimension of SD and the prospects for improving the performance in other dimensions, along with the possibilities of decoupling.

The following three indicators are important representatives of the environmental dimension of SD. As regards SDG11, in both years the Recycling rate of municipal waste was the highest in Germany (63.2% and 66.1% in 2007 and 2016, respectively) and the second highest in Austria (60.2% and 57.6% in 2007 and 2016, respectively). The Benelux countries, Sweden, Finland, and Denmark showed high rates in both years. Finland also showed a significant increase (by 19.3 p.p.), but the highest increase was shown by Lithuania (by 40.5 p.p.). On the other hand, the highest drop occurred in Norway (by 4.4 p.p.) that showed one of the highest share in 2007 (42.6%) as well. The new member countries and Southern countries showed low and medium rates in 2007 (only Spain's rate exceeded the average). This is also the case for 2016, but the rates of Poland, Italy, and Lithuania were higher (above the average), that of Slovenia was even fourth highest in the sample (54.1). Accordingly, the highest means and medians are typical of cluster 1 followed by cluster 4 in both years, while their lowest levels were achieved in cluster 2 in 2016 and in cluster 3 in 2007.

The decoupling indicator of Resource Productivity (representing SDG12) is crucial for achieving SD. In 2016, Italy showed the highest Resource Productivity (3.998 PPS per kg). This was followed by the Netherlands (3.99 PPS per kg), the UK (3.63 PPS per kg), Luxembourg (3.57 PPS per kg), and Spain (3.19 PPS per kg), all showing levels above 3 PPS per kg. The lowest levels in both years are typical of Bulgaria, Romania, Latvia, Estonia, Finland, and Poland, all showing the lower level than 1 PPS per kg in 2016. Another three countries showed lower levels than 1 PPS per kg in 2007, i.e., Ireland, Slovenia, and Cyprus. However, all three countries showed significant increases, while that of Ireland was the third highest in the sample following Italy and Spain. Accordingly, cluster 1 showed the best performance. Cluster 2 showed the poorest performance in the initial period because it includes

only Bulgaria that showed the lowest Resource Productivity. In the recent period, the mean and median of Resource Productivity in cluster 4 showed the lowest value. It is the lowest in Finland (0.96 PPS per kg), the indicator is also relatively low in Norway (1.27 PPS per kg) and Sweden (1.51 PPS per kg), and medium in Denmark (1.74 PPS per kg).[1] All these levels are below the average of the sample.

As regards the SDG13R indicator, the highest levels were shown by Norway (60.1 (2007) and 69.4% (2016)), followed by Sweden (44.2 (2007) and 53.8% (2016)), Finland (29.6 (2007) and 38.7% (2016)), Latvia (29.6 (2007) and 37.2% (2016)), Austria (27 (2007) and 33.5% (2016)) in both years, and Denmark in the recent period (32.2% in 2016). The latter showed a lower level in 2007 (17.8%), but the highest increase in the sample (14.4 p.p.). The other two Baltic countries, Estonia and Lithuania, showed relatively high shares as well (above the average levels in both years). Moreover, all Northern and Baltic countries, along with Bulgaria, but also Spain and Italy, showed great increases between 2007 and 2016. The lowest shares are typical of the Benelux countries, Malta, Cyprus, the UK and Ireland, while they also showed low increases (except for the UK where the increase was higher), along with Slovakia and Poland (in no country of the sample did the share decrease).

As regards the SDG16 indicator, all four Northern countries showed the highest levels in both years; Denmark exceeded Finland in 2016 and they are followed by Sweden and Norway in both years. Other countries with a high performance are the Benelux countries, the UK, and Germany. A low performance is a characteristic of a number of new member countries, with the lowest shown by Bulgaria, along with Greece and Italy. Cyprus showed a relatively good performance in 2007, but the highest drop of the score in the sample as well. Currently, Estonia, followed by Poland and Slovenia, are the best-performing new member countries in 2016.

The SDG17 indicator, i.e., Shares of environmental taxes in total tax revenues, was higher than 10% in two countries in 2016 (Latvia: 11.69%; Slovenia: 10.57%) and in three countries in 2007 (Malta: 10.75%; Denmark: 10.21%; Bulgaria: 10.11%). The lowest shares are in Luxembourg in the recent years (4.58%) and in Germany in both years (5.81% (2007) and 4.77% (2016)), France (4.4% (2007) and 4.89% (2016)), Belgium (5.71% (2007) and 4.99% (2016)), Sweden (5.59% (2007) and 5.05% (2016)), and Spain (4.86% (2007) and 5.54% (2016)). The highest increase was achieved by Latvia (4.47 p.p.) followed by Greece (3.3 p.p.), and the highest drop by Luxembourg (−2.49 p.p.), followed by Malta (−2.22 p. p). It is difficult to assess the effects of environmental taxes. It requires a detailed analysis, and their particular composition and tax rates are also crucial for SD. Some of the analyzed countries can have as high rates for environmental as for labor taxes. Then it can be at least claimed that the application of the revenue neutrality principle, or an increase in environmental taxes in relation to labor taxes generally, should stimulate decoupling and SD in general. More particularly, it can affect the relationships

[1]The other non-EU country, Switzerland, showed the absolutely highest level of the indicator in both years (3.33 and 4.07 PPS per kg in 2007 and 2016, respectively). It was excluded from the analysis due to the missing data for several indicators.

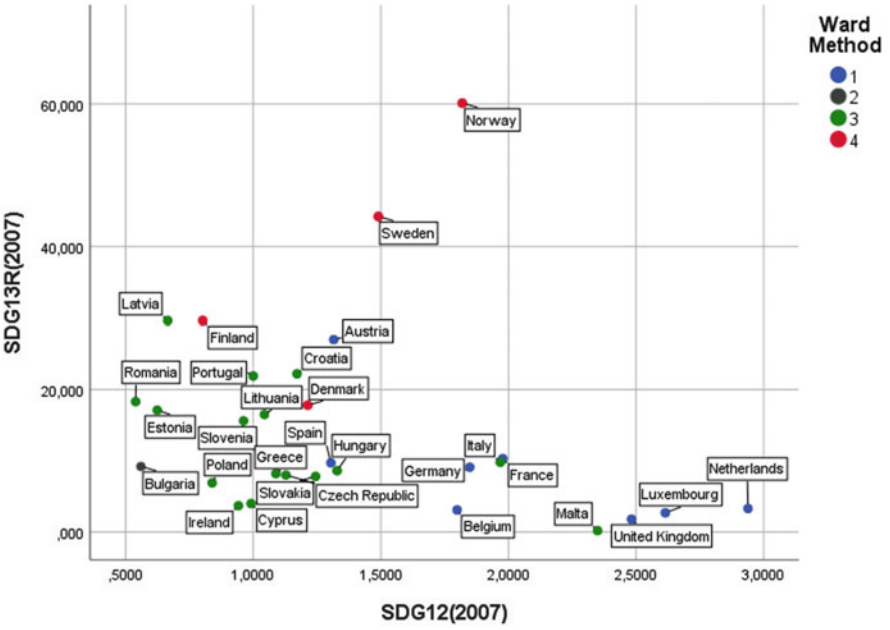

Fig. 3 Resource Productivity in PPS per kilogram (SDG12) and Share of renewable energy in gross final energy consumption (%) (SDG13R), 2007 (Source: Eurostat, 2018a; author's elaboration)

between the economic and the environmental pillar in such a way so as to encourage the shifts toward SD. This is reflected in the SDG17 indicator. There is no clear pattern and similarities as regards the allocation to clusters, but, on average, cluster 2 showed the highest shares, as Bulgaria showed the third highest share in 2007 and in 2016. Except for Spain, all cluster 2 countries also showed medium shares: Lithuania and Portugal (the former slightly below and the latter slightly above the average level) or relatively high shares (the remaining countries included in cluster 2). The values in cluster 4 are scattered, with Denmark showing the highest shares (8.59% in 2016) and Sweden the lowest (5.05% in 2016). On the other hand, Sweden showed the highest shares of labor taxes (57.64% in 2015). Next, the relationships between two crucial indicators mainly representing the environmental pillar, particularly the aspects related to decoupling, i.e., the SDG12 indicator, and climate and energy issues, i.e., the SDG13R indicator, are examined more in detail. The focus is predominantly on the distribution of their levels among clusters.

In both Figs. 3 and 4 it can be seen that the cluster 1 countries are predominantly located in the bottom right corner of Figs. 3 and 4. As regards Fig. 3, several cluster 3 countries are also located in this part, such as Malta and Italy, both showing high Resource Productivity and the lowest and medium Shares of renewable energy, respectively (Malta: 0.2%; Italy: 9.8% in 2007).The bottom right corner looks slightly different in the recent period (Fig. 4). Italy achieved the highest Resource

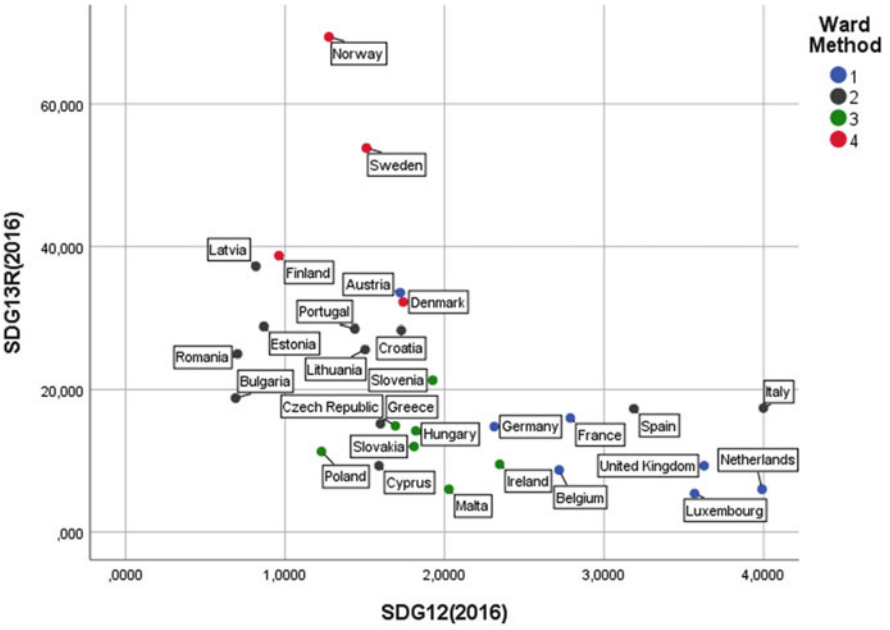

Fig. 4 Resource Productivity in PPS per kilogram (SDG12) and Share of renewable energy in gross final energy consumption (%) (SDG13R), 2016 (Source: Eurostat, 2018a; author's elaboration)

Productivity in the sample and this country shifted to cluster 2 together with Spain (the latter from cluster 1). Both countries showed similar medium Shares of renewable energy (both below the average levels) and high Resource Productivities. The increase in the latter indicator between 2007 and 2016 was the highest in Italy and the second highest in Spain. These two cluster 2 countries are located in the bottom right corner in 2016 along with similar cluster 1 countries as in the initial period: the Benelux countries, the UK, Germany, and France. In addition to Malta, the other cluster 3 country, Ireland, is located there in 2016. Ireland achieved the third highest increase in Resource Productivity between 2007 and 2016, following Italy and Spain. All the indicated countries achieved relatively high Resource Productivities and low (Malta, Benelux, the UK, and Ireland) or medium, but still below average (Germany, France, Spain, and Italy) Shares of renewable energy. In the upper middle part, there are two cluster 4 countries—Norway and Sweden, both showing the highest Shares of renewable energy, while in both countries these shares significantly increased between 2007 and 2016 (the fourth highest increase in Sweden and the fifth highest in Norway in the overall sample). On the other hand, Norway showed the highest decrease in Resource Productivity and Sweden the lowest increase between the years. Thus, in 2016 their Resource Productivities are lower than average as compared to 2007, when they achieved higher than average levels in the overall sample. The remaining cluster 4 countries also showed relatively high

Shares of renewable energy, but their Resource Productivities are below average in both years and, moreover, in Finland, among the lowest. In the left part, the cluster 3 countries in 2007 (Fig. 3) and cluster 2 countries in 2016 (Fig. 4) prevailed. Bulgaria, Romania, Latvia, and Estonia are the countries located in the left corners with the lowest Resource Productivities in both years, but showing relatively high Shares of renewable energy. Only those of Bulgaria are below average levels, while those of Latvia are one of the highest in the sample.

Although no clear relationships were observed between the two indicators, some patterns were detected in respect to the classification of countries into four clusters. Overall, rather negative relationships between the SDG12 indicator and the SDG13R indicator can be seen in the sample, while the correlation coefficient (r) is higher in 2016 (-0.242 (2007); -0.503 (2016)). The absolute value of the coefficient increases when Norway and Sweden are omitted ($r = -0.565$ (2007); -0.583 (2016)). It is crucial to examine relationships between the crucial indicators reflecting the SD aspects to reveal the factors determining SD and the possible trade-offs.

4.3 Overall Assessment of the Results

It is concluded that cluster 4 is the most sustainable cluster in both years and cluster 2 had the worst performance. Between 2007 and 2016, the composition of the clusters changed, except for cluster 4. The major changes occurred between clusters 2 and 3. In cluster 1 the number of countries was reduced by one country—Spain, while all the other developed EU countries remained in this cluster. Cluster 4 contains the four developed Northern countries in both years. In cluster 3, which contained almost all the new member countries and Southern countries, the number of countries was significantly reduced from 16 to 7, while all of them shifted to the worst-performing cluster, cluster 2. These countries are the three Southern countries: Greece, Italy, Portugal, the three Baltic countries, and the other less developed new member countries: Croatia, Cyprus, and Romania. Thus, in cluster 3, the other new member countries remained: the CR, Hungary, Slovenia, Slovakia, Poland, and Malta, along with Ireland.

To sum up, the majority of changes in the indicator values in the four clusters between 2007 and 2016 indicated the shifts toward higher sustainability, especially for the three indicators representing the environmental dimension of SD, i.e., SDG11, 12, and 13R, where the values increased in all the clusters. The changes toward lower performance and sustainability were predominantly observed in cluster 4, more rarely in cluster 1 that are both the best-performing clusters. However, these changes can be assessed as slight. Another important development is the shift of countries to cluster 2 from cluster 1 (Spain) and from cluster 3 (9 countries: 3 Baltic countries, three Southern countries, Cyprus, Croatia, and Romania), while cluster 2 is still be evaluated as the worst-performing cluster.

Comparing the results to those of the crucial studies included in Sect. 2, there are some similarities, but also significant differences in respect to the classification of countries into the clusters, which predominantly depends on the indicators and the periods included (e.g., Slovakia and Slovenia; Bulgaria and Romania; Greece and Portugal; Germany, France, and the UK; or Northern countries are included together in the same clusters). It can be seen that the Northern countries often show the highest performance, especially Sweden, but the other three countries too. This can be confirmed by this work where all these countries are assigned to the best-performing cluster, cluster 4. Luxembourg, the Netherlands, the UK, and Cyprus were also assessed as the best performers. Moreover, Latvia was evaluated as the good performer in the environmental dimension. The first three countries are included in the second best-performing cluster, cluster 1, where the major deficiency is the low Share of renewable energy, but which has very good results in the majority of other indicators. On the other hand, Cyprus and Latvia showed poor results in more indicators, such as SDG1 (especially Latvia), SDG7 (especially Cyprus), SDG9 (both), SDG10 (Latvia), SDG11 (both), SDG12 (especially Latvia), and SDG13R (Cyprus). However, the great performance of Latvia in Share of renewable energy supports its performance in the environmental dimension and both countries also showed high Shares of environmental taxes in total tax revenues. Both countries were shifted to the worst-performing cluster, cluster 2, in 2016, from cluster 3, where they were included in 2007.

The countries that often showed a low performance in analyzed studies (Sect. 2) are Bulgaria, Romania, the Baltic countries, Slovakia, and Hungary. In this work, the first country is included in the worst-performing cluster 2 in both years. Romania and Baltic countries were shifted to this cluster from cluster 3 in the recent year. Hungary and Slovakia are included in cluster 3 in both years. These countries showed a low performance in a number of indicators, especially Bulgaria and Romania. In particular, in the SDG1, 7, and 10 indicators four countries showed poor results: Bulgaria, Romania, Latvia, and Lithuania. Besides these countries, for the SDG9 indicator also Slovakia and for the SDG12 indicator also Estonia showed poor results, while Lithuania showed slightly higher Resource Productivities. For the SDG11 indicator, it was especially the case for Romania, Latvia, and Slovakia. Lower levels for the SDG13R indicator were shown by Slovakia and Hungary. In the case of the SDG16 indicator, Bulgaria and Romania performed the most poorly, while Hungary (especially in the recent year) and Slovakia also performed badly. Thus, similarities can be confirmed, especially in the cases of Bulgaria, Romania, Latvia, and Lithuania, and to a lesser extent in Slovakia and Hungary. Overall, Slovakia, Hungary, and Estonia did not show such poor results in this work in the majority of the indicators included. On the other hand, for Latvia the results are contradictory to some extent.

5 Conclusions

The aim of this chapter was to form clusters from a group that includes the EU countries plus Norway using their sustainability performance measured by selected indicators included in the EU SDG indicator set. The indicators for all three pillars of SD were applied and special attention was paid to the crucial indicators reflecting decoupling, climate, and energy targets. The levels of sustainability (performance) were evaluated in the sample of 29 countries, i.e., the 28 EU countries and Norway, according to their allocation to particular clusters. The path of SD was assessed according to the changes in the allocation to clusters and the indicator values between two analyzed years. Four clusters were created in the initial year (predominantly 2007) and the recent year (primarily 2016). Sustainability and SD are assessed according to performance in all the dimensions simultaneously, i.e., a lack of progress in one dimension cannot be offset by a good performance in other dimensions.

Cluster 1 is composed of the more developed EU countries, i.e., the Benelux countries, Austria, Germany, France, and the UK, while Spain is included just in the initial year. Cluster 2 includes only Bulgaria in the initial year, but all four Southern countries are included in the recent year. Spain shifted from cluster 1 and the other three countries from cluster 3. Moreover, all three Baltic countries shifted to cluster 2 in the recent year from cluster 3, where they were included in the initial year. This is also the case for Cyprus, Croatia, and Romania. The other seven cluster 3 countries remained there: the CR, Hungary, Ireland, Malta, Poland, Slovenia, and Slovakia. Because no country was added to this cluster in the recent period, the number of countries decreased from 16 to 7. Cluster 4 has the same composition in the initial and the recent year; it is composed of four Northern countries.

For the three crucial social indicators, which are People at risk of poverty or social exclusion, Population unable to keep home adequately warm and Gini coefficient of equalized disposable income, representing SDG1, 7, and 10, respectively, while the SDG7 indicator also reflects socio–energy aspects, cluster 4 is the best-performing cluster and cluster 2 showed the lowest performance in both periods. Similar results are typical of the SDG9 indicator, i.e., gross domestic expenditure on R&D, reflecting the economic dimension of SD and indicating the possibilities of decoupling and improvements in all the dimensions in the future. The highest means and medians, and thus the highest performance, were achieved by cluster 4 and the worst performance by cluster 2 in both years. The changes of means and medians for these indicators between the years predominantly reflect the shifts toward highest sustainability levels, except for those having taken place for both median and mean in cluster 4 for the SDG1 indicator, those in cluster 4 and cluster 1 for the SDG10 indicator and medians in cluster 4 for the SDG7 and SDG9 indicators. Thus, the most sustainable cluster and the second best-performing cluster showed some changes toward lower sustainability levels, while cluster 4 did not even change its composition.

For the three indicators representing the environmental dimension of SD, i.e., Recycling rate of municipal waste (SDG11), Resource Productivity (SDG12), and Share of renewable energy in gross final energy consumption (SDG13R), the results are contradictory to some extent. For SDG11 and SDG12, the highest performance is shown by cluster 1, but this cluster showed a relatively low average Share of renewable energy (SDG13R). On the other hand, cluster 4 showed the highest performance in this indicator, the second best performance in the SDG11 and SDG12 indicators in the initial period, but the lowest performance in the latter indicator in the recent period. For all three indicators representing the environmental dimension of SD, the means and medians increased in all clusters, which could indicate a shift toward higher sustainability and a shift closer to the SD path. A slightly negative relationship was observed between the values of the SDG12 and the SDG13R indicators in the sample. However, no clear patterns were detected.

Finally, SDG16 and SDG17 were evaluated together as the representatives of the institutional dimension, although the SDG17 indicator also reflects the environmental pillar of SD. The highest means and medians and the best performance in the Corruption Perceptions Index (SDG16) were in cluster 4 and the second highest in cluster 1 in both years. The poorest performance is shown by cluster 2. For Shares of environmental taxes in total tax revenues (SDG17), the highest levels are shown by cluster 2 and the lowest levels by cluster 1 in both years. For the SDG16 indicator, the only slight decreases in the mean and median occurred in the best-performing cluster, cluster 4. As regards the SDG17 indicator, the means and medians in clusters 1 and 2 and the mean in cluster 4 declined between the years. On average, cluster 4 can then be evaluated as the best-performing cluster in the institutional dimension, showing the best results for the SDG16 indicator; although the values for the SDG17 indicator are lower. Moreover, the SDG17 indicator is important for SD due to the revenue neutrality principle, it does not reflect environmental and labor tax rates.

Overall, the majority of changes in the indicator values in the four clusters between 2007 and 2016 indicated shifts toward higher sustainability, especially for the three indicators representing the environmental dimension of SD, i.e., SDG11, 12, and 13R, where the values increased in all the clusters. Changes toward lower performance and sustainability were predominantly observed in cluster 4 and more infrequently in cluster 1, which are the two best-performing clusters. However, these changes can be assessed as slight. Another important development is the shift of countries to cluster 2 from cluster 1 (Spain) and from cluster 3 (9 countries: three Baltic countries, three Southern countries, Cyprus, Croatia, and Romania).

It can be concluded that cluster 4 showed the highest performance and sustainability according to most indicators, although slight changes toward higher unsustainability occurred in this cluster predominantly in the economic, social, and institutional dimensions. This cluster did not change its composition between the years and thus the changes, but also its highest performance, are most visible. Cluster 1 was assessed as the second best-performing cluster. Cluster 2 changed the composition significantly (from 1 to 11 countries) and this is the cluster having the lowest average performance and sustainability in both years. The crucial shifts between the compositions of the clusters predominantly took place between clusters 2 and 3. The

assessment of these changes in relation to sustainability is not unambiguous, as many of the countries from both clusters improved their performance. However, cluster 3 shows better results in both years in the majority of the indicators and the changes between the years did not mostly lead to improving the position of cluster 2 in comparison to cluster 3, except for the SDG13R indicator. Moreover, the changes also led to its worsening, such as in the case of the SDG10 and SDG11 indicators. The shift of countries from cluster 3 to cluster 2 can therefore be evaluated as a shift toward lower sustainability when the average values in the recent period are considered. The challenge for the future is to improve the methodologies of SD and decoupling measurement, including the possibilities to apply cluster analysis and its appropriate methods. The methodology related to the constructions of quality SD indicators and indices is also a challenging task.

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