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Assessment of Sustainable Development Using Cluster Analysis and Principal Component Analysis

Ocena zrównoważonego rozwoju za pomocą analizy skupień i analizy głównych składników

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Abstract

The European Union (EU) Sustainable Development Goals (SDG) indicator set replaced the EU Sustainable Development Strategy (SDS) in 2017. The selected indicators of this set were chosen for the analysis to classify the sample of the 28 EU countries along with Norway according to their performance in sustainability. In the selection of indicators, priority was given to the indicators reflecting the social dimension of SD, along with important representatives of the economic, ecological and institutional dimensions of SD generally. Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) were applied to the data of 12 indicators in the period 2012- 2016. By means of the HCA, four clusters were created in each year of the period 2012-2016 using the indicator values of particular years and then using all the indicator values in all the monitored years for the general assignment of countries to particular clusters. According to changes in the assignment to particular clusters over the years, the sustainability of development and the path of SD in the examined countries are assessed. As regards the core countries of each cluster, cluster 1 includes the most developed EU countries and is thus evaluated as the best performing cluster. Cluster 2 including the least developed EU countries is evaluated as the worst performing cluster. Cluster 3 predominantly includes the transitive economies and it is evaluated as the second best performing cluster according to the indicators applied. Cluster 4 containing the Southern countries is assessed as the second worst performing cluster. From the shifts of countries that occurred between the years, the shift of Ireland from cluster 3 to cluster 1 in 2013 must be emphasised as the move towards higher sustainability. The shift of Slovakia and Hungary from cluster 2 to cluster 3 in 2013 is also evaluated as progress towards higher sustainability.

Key words: European Union (EU), Hierarchical Cluster Analysis (HCA), Principal Component Analysis (PCA), Sustainable Development (SD), Sustainable Development Goals (SDGs), JEL Classification: Q01, Q50, Q51, Q54, Q56

Streszczenie

W Unii Europejskiej w 2017 r. Cele zrównoważonego rozwoju zastąpiły dotychczasową Strategię zrównoważonego rozwoju. W tej pracy wybrane wskaźniki odnoszące się do nowych Celów zrównoważonego rozwoju stanowią podstawę klasyfikacji 28 krajów Wspólnoty oraz Norwegii. Wśród tych wskaźników priorytetowo potraktowano te odnoszące się do wymiaru społecznego zrównoważonego rozwoju, uzupełniając dyskusję o podstawowe wskaźniki ekonomiczne, ekologiczne i instytucjonalne. Przeanalizowano okres obejmujący lata 2012-2016. Wobec wybranych 12 wskaźników zastosowano hierarchiczną analizę skupień i analizę głównych składników. Utwo-

rzono cztery klastry w ramach każdego roku z analizowanego okresu, określając wartości wskaźników dla poszczególnych lat, a następnie określenie wszystkich wartości wskaźników dla wszystkich monitorowanych lat umożliwiło przypisanie krajów do poszczególnych klastrów. Określenie zmian w przypisaniu do poszczególnych klastrów na przestrzeni lat umożliwiło ocenę zrównoważoności rozwoju i określenie ścieżki zrównoważonego rozwoju badanych krajów. Jeśli chodzi o główne kraje każdego klastra, to klaster 1 obejmuje najbardziej rozwinięte kraje UE i dlatego jest oceniany jako klaster, który osiąga najlepsze wyniki. Klaster 2 uwzględnia najsłabiej rozwinięte kraje i oceniony jest jako ten, który osiąga najgorsze wyniki. Klaster 3 obejmuje głównie gospodarki znajdujące się w okresie przejściowym i jest oceniany jako drugi osiągający najlepsze wyniki. Klaster 4 obejmuje kraje Południa i jest oceniany jako drugi osiągający najgorsze wyniki. Uwzględniając zmiany jakie zaszły w okresie kolejnych lat, należy podkreślić przesunięcie Irlandii z klastra 3 do klastra 1 w 2013 r., co oznacza ruch w kierunku większej zrównoważoności. Tak samo należy ocenić przejście w tym samym roku Słowacji i Węgier z klastra 2 do klastra 3.

Słowa kluczowe: Unia Europejska, hierarchiczna analiza skupień, analiza głównych wskaźników, rozwój zrównoważony, cele zrównoważonego rozwoju

1. Introduction

Sustainable development (SD) is a concept that emerged in the context of a growing awareness of an imminent environmental crisis. It became one of the driving forces of world development in the period around the end of the 20th century (Du Pisani, 2006). SD is a visionary development paradigm, but it is a fluid concept. Various definitions of SD have emerged (Drexhage and Murphy, 2010). According to the most quoted definition of the World Commission on Environment and Development (WCED, 1987), SD is *development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* The three-pillar approach to SD is considered in this paper. It is based on that view of SD which refers simultaneously to economic, social and environmental systems, all of which must be sustainable at the same time. This is because each of these pillars is independently crucial and the pillars are interlinked. Moreover, the fourth, institutional dimension is emphasized as the fourth pillar of SD because of its necessity in supporting progress in the previous three pillars and in SD generally (United Nations et al., 2003). It means that the proper institutions are crucial to achieve the path of SD in all economies (see more in Singh et al. (2009). One of the more concrete ways of defining SD/sustainability is represented by the methods of their measurement (Kates et al., 2005). SD includes social, economic and environmental dimensions, along with institutional aspects, and issues related to its measurement have gained great importance. For the assessment of progress towards SD, the statistical tools need to be used (Adamišin et al., 2015). In addition to measuring the performance in each dimension of SD by means of the appropriate indicators used for each of them[1], the relationship between two dimensions (economic and environmental) can be reflected in one indicator. Decoupling indicators measure the extent of decoupling, which is an important process (and concept) for putting the concept of SD into operation. Decoupling refers to breaking the link between two variables, often referred to as driving force, mainly economic growth expressed in terms of GDP, and environmental pressures, such as the use of natural resources, the generation of waste, and the emission of pollutants (OECD, 2002). The purpose of the decoupling indicators is to monitor the interdependence between these two spheres and they usually measure decoupling of the environmental pressure from the economic growth over a given period (OECD, 2003). The concept of decoupling is crucial for the path of SD and decoupling indicators are valuable tools for determining whether countries are on track towards the path of SD (see more also in Drastichová, 2017). Therefore, an important decoupling indicator included in the EU SDG set is applied in the analysis along with other indicators representing particular dimensions of SD.

SD is a fundamental objective of the European Union (EU) enshrined in its primary law (European Union, 2012). *The EU Sustainable Development Strategy* (SDS) was adopted in 2001 and its external dimension in 2002. The United Nations (UN) adopted the *2030 Agenda for Sustainable Development* and its *17 Sustainable Development Goals* (SDGs) in September 2015. They have given a new impetus to global efforts for achieving SD. The EU, in coordination with its Member States, is committed to support the implementation of the *2030 Agenda*. Accordingly, the *EU Sustainable Development Goal (SDG) indicator set* replaced the *EU SDS* in 2017.

The aim of the paper is to cluster the sample, which includes the 28 EU countries and Norway, according to their sustainability levels, to evaluate the extent of sustainability of the created clusters and to discover if shifts closer towards the path of SD took place. The latter is evaluated for the whole sample, for each cluster and at the country level. The selected indica-

[1] An aggregate index can be constructed from the separate indicators to show the overall progress in sustainability and SD (see more for example in Drastichová (2017).

tors included in the EU SDG indicator set are used to measure sustainability levels and their change in the period 2012-2016 to reflect SD. The innovation of this article lies not only in the use of the most recent EU SDG indicator set, but the methodology was fine-tuned in comparison with Drastichová (2017, 2018a) to reflect the aspects of SD more properly. This article has a more significant focus on the development of sustainability over time rather than sustainability at a particular point in time. This reflects the extent of movement towards the path of SD and SD can be measured more precisely. In this article, the Northern countries consist of Denmark, Finland, Norway and Sweden (and Iceland when it is included); Greece, Italy, Portugal and Spain constitute the Southern countries; the Baltic countries comprise Estonia, Latvia and Lithuania; and the new member countries are those which joined the EU in 2004 or later. The attribute *core* is used in relation to the countries that created the core of a particular cluster in each or in the majority of the years included.

2. Theoretical Background (Literature Review)

A number of studies have dealt with the evaluation of SD in the EU using cluster analysis. Those and other works that are relevant for the analysis carried out in this paper are introduced in this section.

Allievi et al. (2011) applied a Hierarchical Cluster Analysis (HCA) to the EU-27 countries based on their performance measured by the *EU Sustainable Development Indicators (SDIs)*. 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. For each indicator, the best performing country was assigned the number of points equal to the weight of the indicator, while the worst performing country was 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. Accordingly, the authors 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 environmental dimension, the indicators included are Final energy consumption of road transport per capita; Renewable energy (% of gross electricity consumption); Municipal waste generated per capita; Motorization rate; Emissions of particulate matter from road transport per capita; Emissions of acidifying substances per capita; Emissions of ozone precursors per capita; Domestic Material Consumption per capita; and Area under organic farming (% of utilized agricultural area). Latvia showed the highest performance in both years. Luxembourg showed 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 indicators included are Total R&D expenditure (% of GDP); General government gross debt; GDP per capita in Purchasing Power Standards (PPS) (EU-27 = 100); Energy dependency; and Total employment rate (%). The UK followed by Denmark achieved the highest performance 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). In the social dimension, the indicators included are Total long-term unemployment rate (%); Life expectancy at age 65 for males; Suicide death rate; Persons with low educational attainment (%); and Early school-leavers (%). 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.

It should be emphasised that although Cyprus showed the high performance in the social dimension of SD, its performance in the environmental pillar was very low. According to the strong sustainability principle, one dimension cannot be offset by the others and thus the SD path cannot be pursued in this way. On the other hand, Sweden achieved a high performance in all three dimensions.

Huttmanová (2016) evaluated the management of SD in the 28 EU countries by means of selected indicators characterizing SD and its main dimensions. Nine headline EU SDI indicators were chosen representing given themes (see more about the EU SDIs in section 2). The indicators were: Real GDP per capita (Socio-economic development theme); Resource Productivity (Sustainable consumption and production theme); Persons at-risk-of-poverty or social exclusion (Social inclusion theme); Healthy life years and life expectancy at birth (Public health theme); Primary energy consumption (Climate change and energy theme); Energy consumption of transport relative to GDP and Greenhouse gas (GHG) emissions by transport mode (Sustainable transport theme); and CO_2 emissions per inhabitant in the EU and in developing countries (Global partnership theme). The HCA method was applied, and for the measurement of distance between individual points, Euclidean distance and the method of the nearest neighbour were used. The countries are grouped into two relatively separated clusters. Cluster 1 is composed of Germany, France, Italy, the UK and Spain. Cluster 2 is composed of the remaining countries, which also create separated clusters: 2a) Belgium, Austria, Sweden, Denmark, Ireland, Finland, Netherlands; 2b) Bulgaria, Estonia, Croatia, Lithuania, Slovakia, Latvia, Cyprus, Malta, Slovenia, Hungary, the CR, Greece, Portugal; 2c) Poland; 2d) Luxembourg. Poland and Luxembourg were not

classified because it was not possible to assign them definitely to any of the clusters. Within the second cluster, in multiple clusters, the closest linkage, i.e. the highest extent of similarity, is shown by the following countries: 1) Croatia, Lithuania and Slovakia; 2) Denmark and Ireland; and 3) Greece and Portugal.

Drastichová (2017) evaluated sustainability in the EU countries along with another two developed countries (Norway and Switzerland) according to the wellbeing which they achieved in three dimensions of SD, and aspects of decoupling. An HCA was applied. The 30 countries were evaluated according to the values of three indices: the Sustainable Society Index (SSI) and the Sustainable Development Index (SDI) representing the wellbeing approach, and the Resource Productivity (RP) indicator representing the decoupling approach. The SDI was created from the SSI using several author's modifications. Three clusters were created from the analysed countries based on the values of RP (2016) and three sub-indices composing the SDI (2016). These three sub-indices represent three wellbeing dimensions, i.e. the human, environmental and economic wellbeing dimension (referred to as HW, ENW, and ECW respectively). Cluster 1, consisting of all four Northern countries, two Baltic countries – Estonia and Lithuania, Austria, the CR, Germany, Poland, and Slovenia, showed the highest mean and median values for both human and economic wellbeing. This cluster also showed their lowest levels in the ENW indicator. Cluster 3, including all the remaining 8 new member countries along with Greece, Ireland, and Portugal, had the highest mean and median in the ENW indicator, but it also had the lowest average levels in the remaining three indicators. Cluster 2, consisting of the Benelux countries, two Southern countries – Italy and Spain, as well as France, Switzerland, and the UK, had the highest mean and median for the RP indicator and medium levels were achieved for the three wellbeing indicators. Switzerland was evaluated as the best performing country because it achieved the highest SDI, SSI as well as the RP. As regards the evaluation of the sustainability of clusters, the conclusions of this work were not unambiguous. It was discovered that a high level of human wellbeing has often been achieved at the expense of declining environmental wellbeing. Accordingly, imbalances between the ENW on the one hand and the ECW and ENW often prevailed. A similar analysis was carried out in Drastichová (2018b), where these countries, along with Iceland, the USA and Canada, were grouped into three clusters in 2016 according to the above-described SSI and SDI and another five composite indices, often reflecting all three dimensions of SD. Cluster 1 is composed of all five Northern countries (including Iceland), Switzerland, Austria, Ireland, Lithuania and Slovenia. Cluster 3 contains only Canada, the USA, Estonia and Luxembourg. Cluster 2 is then composed of the remaining, especially transitive, countries, along with two Benelux countries, all the Southern countries, Germany, the UK and France. Cluster 3 showed the worst results in the majority of indicators and the opposite is true for cluster 1.

This work also follows the analysis carried out in Drastichová (2018a), where the selected indicators of the EU SDG indicator set were chosen for the HCA to classify the 28 EU countries, Norway and Switzerland according to their sustainability levels. Four clusters were created according to the indicator values in the initial period (primarily 2007) and the recent period (predominantly 2016). The changes in the assignment to the clusters also reflected the shifts to/from the path of SD. The shift towards SD was especially identified in Slovenia. Cluster 1 (including the Benelux countries, the Northern countries, Austria, France, Germany, the UK and Switzerland in 2007, and these countries along with Slovenia in 2016) was evaluated as the most sustainable cluster. Cluster 2 (including Bulgaria, Latvia, Lithuania and Romania in 2007, and Bulgaria and Lithuania in 2016) was evaluated as the least sustainable one. In several important aspects of SD, cluster 3 also achieved a high performance, while cluster 4 often showed a poor performance. In 2007, cluster 3 included the remaining eight new member countries, apart from Malta. In 2016, it also included Ireland and Latvia, but Cyprus and Slovenia were not included. Cluster 4 was composed of four Southern countries and Malta in both years, along with Ireland in 2007, and along with Cyprus and Romania in 2016. In the combination of the crucial indicators representing the social dimension of SD, which are People at risk of poverty or social exclusion (SDG 1) and Life expectancy at birth (SDG 3), the poorest results were shown by Bulgaria, Romania, Latvia and Lithuania (cluster 2 countries in the initial period). The non-EU countries – Switzerland and Norway, included in cluster 1, were evaluated as the best performing countries. Both indicators are also used in the analysis of this work. Overall, Switzerland, Norway and Sweden were evaluated as the best performing countries. Although the cluster 2 countries showed the highest growth rates in real GDP (the SDG 8 indicator in that work), the initial four cluster 2 countries still showed a poor performance in a number of indicators in 2016.

Several studies have examined particular aspects related to sustainability. Halasková (2015) applied a HCA to selected categories of R&D expenditure in the EU countries in 2004 and 2013. The countries were divided into three clusters according to their similarities. In 2004, cluster 1 was composed of 11 countries characterised by the relatively high level of R&D, including expenditure on and investment into R&D. The Benelux countries, Denmark, Austria, France, Germany and the UK, along with the CR, Slovenia and Ireland, are included. Cluster 2 comprised 15 countries with a relatively low expenditure

on R&D (the remaining 11 new member countries and the Southern countries). Finland and Sweden formed a separate cluster, cluster 3, achieving the highest expenditure. In 2013, Sweden and Finland formed a cluster, cluster 1, along with Austria, Belgium, Denmark, Germany, France and Slovenia, the latter having shown a significant rise in expenditure. Cluster 2, which showed low expenditure, contained 10 countries in 2013 because three Southern countries (except for Greece), Estonia and Hungary created cluster 3 with the remaining five countries of cluster 1 from 2004. Gross domestic expenditure on R&D is used as one of the indicators in the analysis of this work because this kind of expenditure can significantly affect all pillars of SD and decoupling.
The results of the above-described studies are used for comparisons with the results of this work.

3. Data and Methodology

In this section the source of data used, the indicators and the applied methodology are described.

3.1. Data

The EU SDG indicator set, from which the indicators are used in the analysis, is composed of 100 indicators that are structured along the 17 SDGs. Each goal contains 6 indicators primarily attributed to it, except for goals 14 and 17, which only have 5 indicators. There are also multipurpose indicators. Particularly, 41 of the 100 indicators are used to monitor more than one SDG.
The indicators chosen for the analysis represent particular SDG themes (some of them can also represent other themes if they are multipurpose). They were selected according to the criteria to reflect all the relevant aspects of SD, while priority was given to indicators included in the EU's priorities and its relevant strategies. Although the EU adjusted its framework for the measurement of SD to the global agenda (the 2030 Agenda) and the indicators are currently classified according to the framework of 17 SDGs, a number of indicators are the same or similar to those used under the framework of the EU SDIs. It means that the EU has not changed its priority areas for SD, but the global aspects of pursuing the SD path have been emphasised (Eurostat, 2018a).
The previously used set of indicators to measure the progress towards the EU SDS, which is the EU SDI set, significantly determined the choice of indicators in this work. The *Europe 2020 strategy* (European Commission, 2010) and its indicators as well as the *Resource Efficiency Scoreboard (*the set of indicators related to the *Roadmap to a Resource Efficient Europe*, European Commission, 2011) along with the EU SDI set are considered in the choice of indicators for this analysis. However, the indicators are chosen from the EU SDG indicator set and structured according to this, most recent, set.
All the indicators used in the analysis are indicated in Table 1 representing particular SDGs. It was endeavoured to include in the analysis all three basic pillars of SD, as well as the aspects of decoupling represented by the SDG 12 indicator that is also the headline indicator in theme 2 of the EU SDIs and the lead indicator in its *Resource Efficiency Scoreboard*, along with the institutional pillar, where the relevant SDG16 indicator was chosen. Nevertheless, the major focus is on the social dimension of SD which has recently attracted much attention. The crucial indicators reflecting the areas of health, education and characteristics of the labour market are included. From this point of view, this work is an extension of the analysis carried out in Drastichová (2018a), while the methodology was advanced in order to examine the changes over time more properly. Accordingly, the path of SD, not only sustainability and its changes, can be reflected more precisely.
The selection of indicators included in the EU SDG indicator set was determined by their importance as representatives of the relevant SD pillars. The indicators (or their modifications) serving as headline indicators of the EU SDIs (SDG 1, 3, 12 and 13) (Eurostat, 2018a), the Europe 2020 strategy (SDG 1, 4, 5, 9 and 13[2] and to some extent – SDG 8 as well) (European Commission, 2010), along with the *Resource Efficiency Scoreboard* indicators (SDG 12, 13, and 17) (Eurostat, 2018b), were favoured. In the latter set the SDG 12 indicator is the lead indicator, the SDG 13 indicator belongs to dashboard indicators and the environmental tax revenues (representing SDG 17) are included in thematic indicators.
The inclusion of the SDG 10 and SDG 7 indicators is the innovation of the EU SDG indicator set when compared with the EU SDIs set. The indicators related to the un/employment have also important place in the EU SDI set (as the indicators at lower levels) as well as in the *Europe 2020 strategy*. The SDG 4 indicator is also included in the EU SDI set as the lower level indicator. Overall, there is significant continuity and the indicators included in the EU SDG indicator set have already been included in the crucial EU strategies and indicator sets focused on SD, which were created before this set.
The economic dimension of SD is represented by the SDG 5, 8 and 9 indicators. The sufficiently high levels of the latter indicator are of great importance as they allow for the improvements in the other dimensions while supporting decoupling. The social dimension is reflected in the SDG 1, 3, 4 and 7 indicators. The social aspects are also included in the SDG

[2] In the Europe 2020 strategy the employment rate of the population aged 20-64 is included as one of the headline indicators, while in this work the employment rate of recent graduates (the SDG 5 indicator) is applied. The greenhouse gas emissions (GHG) (the SDG 13 indicator) are measured as index (1990 = 100), while in this paper they are measured in tonnes per capita.

5 and 8 indicators. Therefore, the two latter indicators are the socio-economic indicators having significant effects on the social dimension of SD. The environmental dimension is represented by the SDG 12 indicator, which is also a decoupling indicator, and the SDG 13 indicator, which reflects the crucial global environmental problem of climate change. The SDG 7 indicator can be partly regarded as the environmental indicator, while it also reflects the social aspects of energy supply and policy. Moreover, the SDG 17 indicator is used as the representative of both the institutional and environmental aspects. It is difficult to assess the effects of environmental taxes and a detailed analysis is necessary. Their particular composition and tax rates are crucial for SD as well. Some countries can have as high rates of environmental as of labour taxes. Thus, it can be at least concluded that the application of the revenue neutrality principle, or an increase in environmental taxes in relation to labour taxes generally, should stimulate decoupling and SD. More particularly, this can affect the relationships between the economic and environmental dimensions of SD in such a way as to shift the economy closer towards SD. Therefore, reflecting the revenue neutrality principle, the higher the share, the better is the performance generally achieved, but taking into account that there are many other factors that need to be considered. The SDG16 indicator is a direct representative of the institutional pillar of SD.

In summary, a directly proportional relationship between performance in sustainability and the value of indicator exists for the SDG 3, 5, 9, 12, 16 and 17 indicators, and an indirectly proportional relationship for the SDG 1, 4, 7, 8, 10 and 13 indicators.

3.2. Methodology

Cluster analysis is a multidimensional statistical method which aims at sorting different objects (or cases, observations) into groups in a way that the degree of association between two objects is maximal if they are part of the same group and minimal otherwise (Mooi and Sarstedt, 2011). HCA (applied in this work) is a method for cluster analysis which attempts to identify relatively homogeneous groups of cases, or variables, based on selected characteristics, using an algorithm that starts with each case (or variable) in a separate cluster and combines clusters until only one is left.

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 (Everitt, 1993). Ward's method is used as a cluster method in this work. Because quantitative variables are used, the squared Euclidean distance was chosen from the measures for interval to specify distance. As the variables included are measured in different units, the Z scores were chosen from the available standardization methods (Aldenderfer and Blashfield, 1984; Meloun and Militký, 2002; Řezánková, Húsek and Snášel, 2007).

Principal Component Analysis (PCA) is a dimension-reduction tool that is applied to reduce a large set of variables to a small set that still contains most of the information in the large set. PCA is a mathematical procedure which transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables named principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible (Johnson and Wichern, 2007).

An HCA was applied to create the clusters of analysed countries based on the indicator values in every year of the period 2012 – 2016. Moreover, the data for all indicators in all the years are applied to create the overall classification. A PCA was applied to detect the tendency of countries to belong to particular clusters including development over time.

4. Results of the Analysis

The results of the HCA and the PCA are presented in this section. The development over time is analysed in more detail. In all the Figures created, cluster 1 is marked with black, cluster 2 with red, cluster 3 with green and cluster 4 with blue colour.

4.1. Assignment of countries to particular clusters and development over time

The HCA was applied to cluster the countries in each year of the period 2012-2016 as well as according to all values of all indicators used in the whole monitored period. Figure 1 displays a biplot created by means of the PCA, which indicates the composition of clusters in 2012. It can be seen that there are groups of countries which are close to one another for particular indicators. Figure 1 also displays the countries that tend to achieve high or low values of particular indicators in 2012. Figure 3 then shows the shifts of countries that occurred between the years as well. This determines the composition of clusters created by means of the HCA. Particularly, it can be seen that the Northern countries, the Benelux countries, Austria and Germany showed high values of the SDG 5, 9, 13 (in the latter – except for Sweden) and 16 indicators and low values of the SDG 1 and SDG 7 indicators. France and Belgium showed the lowest values of the SDG 17 indicator, while Slovenia, Latvia and Bulgaria showed the highest values. Overall, Bulgaria showed the highest values of the SDG 1 and 7 indicator, Spain of the SDG 3 and 4 indicator, Malta of the SDG 5 indicator, Greece of the SDG 8 indicator, Finland of the SDG 9 and 16 indicators, Latvia of the SDG 10 indicator, Luxembourg of the SDG 12 and 13 indicators and finally, Slovenia of the SDG 17 indicator. On the contrary, Norway showed the lowest value of the SDG 1, 8

Table 1. 12 indicators chosen for the cluster analysis and the data modifications Source: Eurostat (2018a)

SDG / Indicators used
SDG1: People at risk of poverty or social exclusion (percentage)
SDG3: Life expectancy at birth (years)
SDG4: Early leavers from education and training (% of population aged 18 to 24) (Early leavers)
SDG5: Employment rates of recent graduates (% of population aged 20 to 34 with at least upper-secondary education)
SDG7: Population unable to keep home adequately warm (% of population)
SDG8: Long-term unemployment rate (% of active population)
SDG9: Gross domestic expenditure on R&D, All sectors (% of GDP)
SDG10: Gini coefficient of equivalised disposable income (coefficient of 0 (maximal equality) to 100 (maximal inequality)) (Gini coefficient)
SDG12: Resource productivity (PPS per kilogram)
SDG13: Greenhouse gas emissions (tonnes per capita)
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)

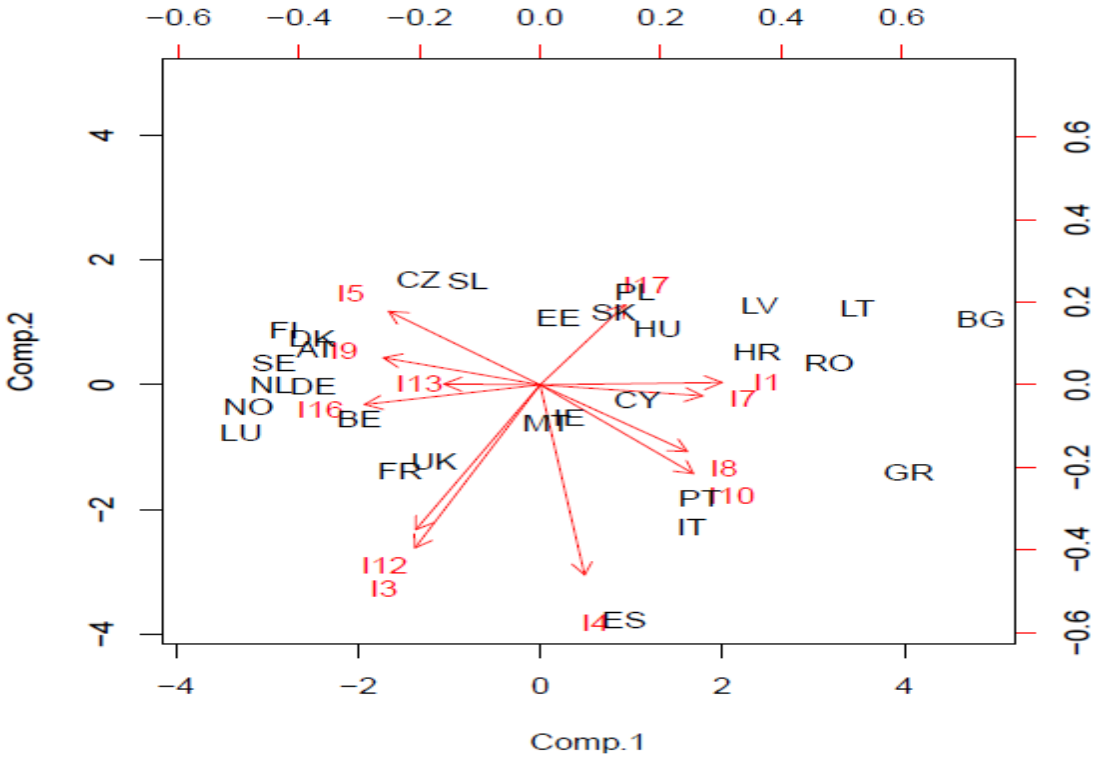

Figure 1. Biplot – results of the Principal Component Analysis, 2012, source: author's calculations

and 10 indicators, Latvia of the SDG 3 and 13 indicators, Slovenia of the SDG 4 indicator, Greece of the SDG 5 and 16 indicators, Luxembourg of the SDG 7 indicator, Cyprus of the SDG 9 indicator, Romania of the SDG 12 indicator and France of the SDG 17 indicator. This already indicates that the Northern countries achieved a high performance in sustainability and in many aspects, the Southern countries and several new member countries showed a poor performance.

After explaining the rationale behind the initial composition of the clusters, the dendograms displayed in Figure 2 indicate the composition in particular years. The assignments to clusters in particular years, which result from Figure 2, are shown in Table 2. Moreover, applying the PCA, Figure 3 indicates the directions and changes in the assignment to clusters in more detail. The dots show the PCA scores for the year 2012. The values of the remaining years are projected into this PCA plane, and their projected coordinates are connected by lines to subsequent years. The colour of the line corresponds to the cluster membership in the corresponding year. For particular countries, different shifts over the years were identified and for some of them a change in the cluster membership occurred. Cluster 1 is the most stable one. The countries of the other clusters predominantly tended to move towards cluster 1. This can especially be seen in the case of Ireland, which finally moved to cluster 1.

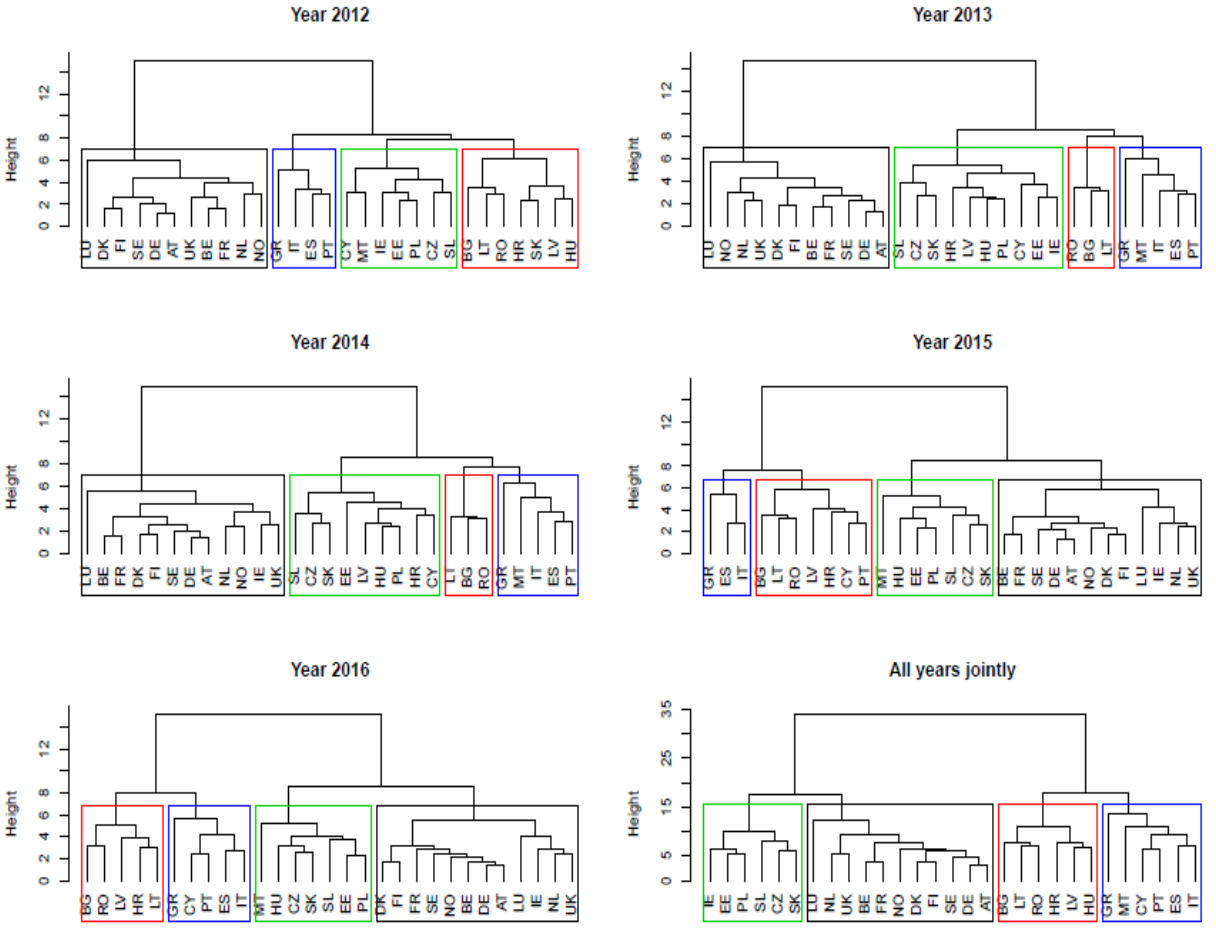

Figure 2. Cluster dendograms created for the values of the 12 indicators used in the particular years of the period 2012 – 2016 and based on all indicators in all years, source: author's calculations

Table 2. Assignment to the clusters 1 – 4 in the years 2012 – 2016, source: author's calculations

C.	2012	2013	2014	2015	2016	C.	2012	2013	2014	2015	2016
BE	1	1	1	1	1	LU	1	1	1	1	1
BG	2	2	2	2	2	HU	2	3	3	3	3
CZ	3	3	3	3	3	MT	3	4	4	3	3
DK	1	1	1	1	1	NL	1	1	1	1	1
DE	1	1	1	1	1	AT	1	1	1	1	1
EE	3	3	3	3	3	PL	3	3	3	3	3
IE	3	3	1	1	1	PT	4	4	4	2	4
GR	4	4	4	4	4	RO	2	2	2	2	2
ES	4	4	4	4	4	SL	3	3	3	3	3
FR	1	1	1	1	1	SK	2	3	3	3	3
HR	2	3	3	2	2	FI	1	1	1	1	1
IT	4	4	4	4	4	SE	1	1	1	1	1
CY	3	3	3	2	4	UK	1	1	1	1	1
LT	2	2	2	2	2	NO	1	1	1	1	1
LV	2	3	3	2	2						

Note: C. – Country

All the cluster 1 countries, which were assigned to this cluster in the first year (2012), remained in this cluster in all the years. These countries are all the Northern countries, the Benelux countries, Germany, France, Austria and the UK. Ireland shifted to this cluster in 2014 from cluster 3 and remained there in 2015 and 2016 as well. This shift is best seen in Figure 3. Only Bulgaria, Romania and Latvia remained in cluster 2 for the overall monitored period (the core cluster 2 countries). However, Croatia and Lithuania shifted to this cluster again after they had shifted to cluster 3 in 2013 and remained there in 2014. Several changes occurred in cluster 4, where three countries remained for the whole monitored period and another three countries for some years. Three Southern countries – Greece, Spain and Italy,

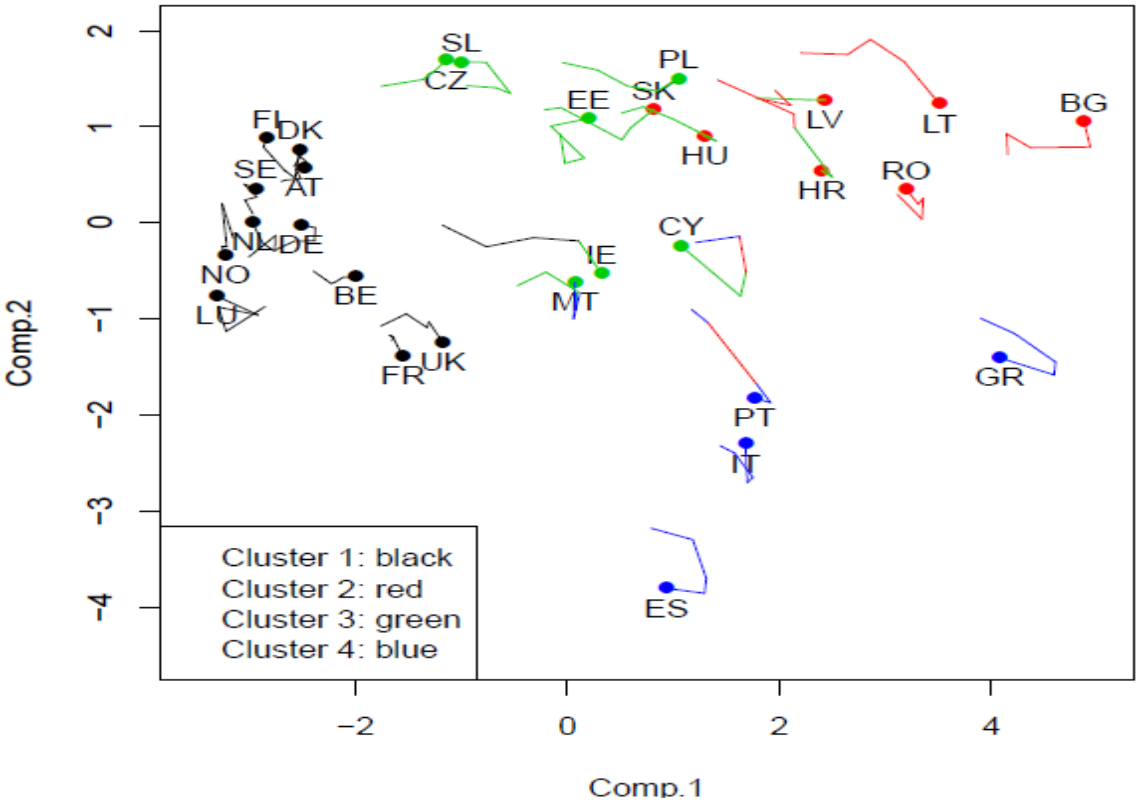

Figure 3. Change in the assignment of countries to the clusters in the period 2012 – 2016, source: author's calculations

Table 3. Mean values of the indicators in particular clusters in the years 2012 – 2016, source: author's calculations

C./ind.	**1(12)**	**3(12)**	**4(12)**	**5(12)**	**7(12)**	**8(12)**	**9(12)**	**10(12)**	**12(12)**	**13(12)**	**16(12)**	**17(12)**
cl. 1	18.400	81.118	10.255	84.345	3.436	2.100	2.399	27.136	2.411	11.400	80.455	6.372
cl. 2	35.400	75.129	9.943	69.929	20.886	6.971	0.777	31.243	0.749	6.829	47.857	7.647
cl. 3	23.657	79.271	9.757	77.071	13.057	4.686	1.454	28.657	1.144	11.457	60.571	8.426
cl. 4	29.250	81.550	18.450	57.050	20.875	9.700	1.160	33.850	1.903	8.200	51.500	7.235
C./ind.	**1(13)**	**3(13)**	**4(13)**	**5(13)**	**7(13)**	**8(13)**	**9(13)**	**10(13)**	**12(13)**	**13(13)**	**16(13)**	**17(13)**
cl. 1	18.582	81.336	9.445	83.655	3.845	2.227	2.405	27.209	2.436	11.245	80.636	6.285
cl. 2	41.667	74.767	13.200	71.033	26.900	5.433	0.543	35.067	0.368	6.433	45.667	9.553
cl. 3	25.730	78.120	7.140	71.450	12.500	6.150	1.308	29.370	1.057	9.770	57.400	7.649
cl. 4	28.600	82.060	17.980	61.660	21.520	10.120	1.098	32.600	2.022	7.660	52.000	7.750
C./ind.	**1(14)**	**3(14)**	**4(14)**	**5(14)**	**7(14)**	**8(14)**	**9(14)**	**10(14)**	**12(14)**	**13(14)**	**16(14)**	**17(14)**
cl. 1	19.475	81.700	8.708	82.675	3.917	2.642	2.328	27.892	2.426	10.825	80.583	6.306
cl. 2	37.700	74.667	13.167	69.533	23.400	4.767	0.620	35.300	0.366	6.600	47.000	10.047
cl. 3	24.456	78.133	6.767	74.500	11.533	5.633	1.253	30.133	0.966	9.233	56.889	7.763
cl. 4	28.960	82.280	16.720	63.360	22.480	10.240	1.084	32.760	1.962	7.580	52.800	7.912
C./ind.	**1(15)**	**3(15)**	**4(15)**	**5(15)**	**7(15)**	**8(15)**	**9(15)**	**10(15)**	**12(15)**	**13(15)**	**16(15)**	**17(15)**
cl. 1	19.133	81.583	8.850	83.292	3.750	2.592	2.326	27.775	2.424	10.725	82.250	6.311
cl. 2	31.929	77.100	9.943	72.514	22.843	5.886	0.811	35.100	0.784	7.286	54.000	8.890
cl. 3	21.400	78.500	9.571	80.314	7.057	3.657	1.419	27.843	0.980	9.171	58.714	7.797
cl. 4	31.000	82.267	14.200	52.967	18.933	12.167	1.177	33.733	2.379	7.967	49.333	8.027
C./ind.	**1(16)**	**3(16)**	**4(16)**	**5(16)**	**7(16)**	**8(16)**	**9(16)**	**10(16)**	**12(16)**	**13(16)**	**16(16)**	**17(16)**
cl. 1	18.867	81.808	8.258	84.308	3.358	2.392	2.318	28.075	2.519	10.717	81.000	6.296
cl. 2	33.140	75.640	9.980	75.520	20.440	4.220	0.680	34.740	0.605	6.640	50.800	9.210
cl. 3	20.357	78.914	9.586	83.129	5.643	2.914	1.220	27.571	1.019	9.343	57.429	7.829
cl. 4	29.260	82.480	12.120	63.460	20.420	9.040	1.052	33.580	1.941	8.300	53.200	7.990

Note: i. – indicator, c. – country, cl. – cluster; Indicators are labelled only by the number of the SDG and last two numbers of the year.

were included in all the years and the remaining Southern country – Portugal, shifted from cluster 4 to cluster 2 for only one year, 2015. All four Southern countries are the core cluster 4 countries. Malta shifted to this cluster from cluster 3 for two years, 2013 and 2014, and then it was assigned to cluster 3 again. Cyprus ended

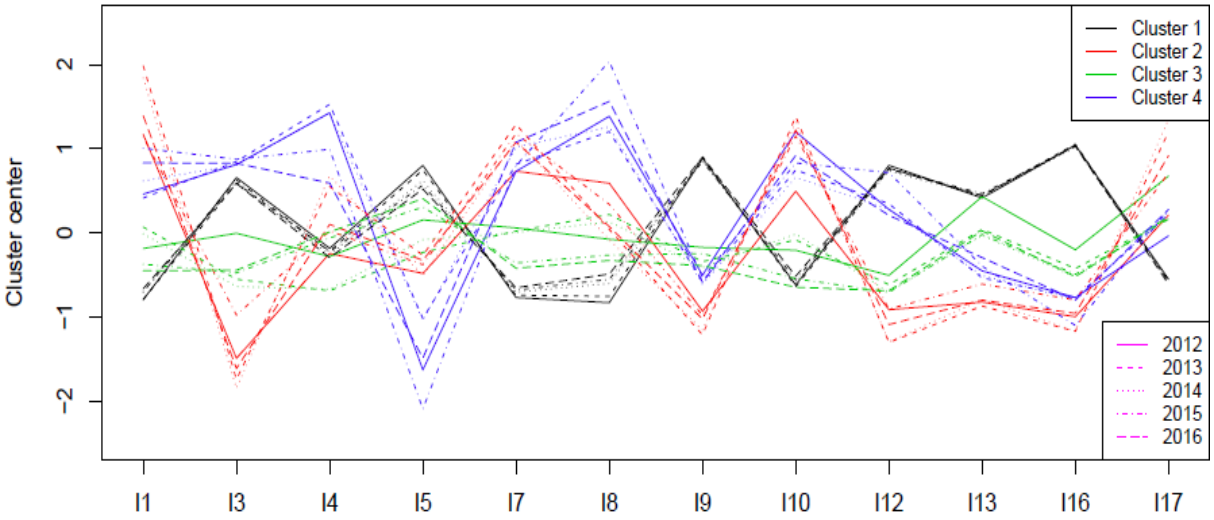

Figure 4. Changes of cluster mean values for the standardized values of the indicators in the period 2012 – 2016, source: author's calculations
Note: i. – indicator

up in cluster 4 after being in cluster 3 for the first three years and in cluster 2 in 2015. The CR, Estonia, Poland and Slovenia were included in cluster 3 in all the monitored years (the core cluster 3 countries). Slovakia and Hungary shifted to cluster 3 and remained there after being included in cluster 2 in the first year, 2012.

Table 3 displays the mean values of particular indicators for particular clusters in each year. Cluster 1 achieved the lowest mean values for the SDG 1, SDG 7, SDG 8 and SDG 17 indicators in all the monitored years. As regards the first three indicators (SDG 1, 7 and 8), these are the best results among the clusters. This cluster also displayed the lowest mean values of the SDG10 indicator in all the years except for 2016 when it was slightly surpassed by cluster 3. The lower the coefficient, the higher the level of equality achieved, and therefore the performance is highest among the clusters as well (except for 2016). This cluster also achieved the lowest mean values of early leavers (the SDG 4 indicator) in the two most recent years, 2015 and 2016.

Cluster 2 showed the lowest mean values for the SDG 3, SDG 9, SDG 12 and SDG 16 indicators (in the latter – except for 2015), where a positive relationship between the indicator value and the achieved performance exists. Therefore, this cluster shows the lowest performance in these indicators. Moreover, the lowest values of the SDG 13 indicator were also shown in all the monitored years. Accordingly, this cluster achieved the best results because of the indirectly proportional relationships. The highest mean values were shown in the SDG 1, SDG 7 and SDG 10 indicators (in the latter – except for 2012), where an indirectly proportional relationships exist, which indicates the lowest performance. Moreover, the highest mean values were also shown in the SDG 17 indicator (except for 2012), where the positive relationships were determined, indicating positive results for sustainability.

Cluster 3 showed the lowest average values of early leavers (the SDG 4 indicator) in the first three monitored years. As indicated above, the lowest level of the Gini coefficient (the SDG 10 indicator) was achieved by this cluster in 2016 reflecting the highest average equality among the clusters. The highest mean of shares of environmental taxes (the SDG 17 indicator) was achieved in 2012. All these values reflect the highest performance, but it can be seen that in this cluster for no indicator the highest average performance is achieved in all the monitored years. On the other hand, this cluster did not show the lowest average performance, apart from the SDG 13 indicator in 2012. Its average emissions were slightly higher than those of cluster 1. Cluster 4 showed the lowest mean values for the SDG 5 indicator and the highest ones for the SDG 3, SDG 4 and SDG 8 indicators. The highest mean of the Gini coefficient (SDG 10) among clusters was shown in 2012. The highest mean values of the SDG 3 indicator indicate the greatest performance among the clusters. On the other hand, the highest mean values of the SDG 4 and SDG 8 indicators and the lowest mean values of the SDG 5 indicator reflect the lowest performance among the clusters. All these aspects are related to the social dimension of SD. On the one hand, the highest average life expectancies were achieved. On the other hand, significant deficiencies were identified in the field of un/employment, education and un/equality. The lowest standard deviation (StD) values were in cluster 1 in all the years for the SDG 4, 5, 7 and 8 indicators as well as for the SDG 3 indicator (except for 2013 and 2014). For the SDG 5 indicator, the highest StD values were in cluster 4, while those of 2013 and 2014 in this cluster are the highest values among all the indicators in all the years (above 20). For the SDG 9 indicator the variance is among the lowest in all the clusters generally (below 1 for all the indicators in all the years).

Next, the results are summarized. All the aspects described can be seen in Table 3, 5 and Figure 4. For People at risk of poverty or social exclusion (SDG 1), clusters 1 and 2 are at opposite ends of the scale, with cluster 1 showing the best results and cluster 2 the worst. The average shares of the second best performing cluster, cluster 3, were substantially higher than those of cluster 1 in the first three years. However, in the last two years these differences diminished (see Table 3). Although the average shares declined in cluster 2 and 3, they slightly increased in both cluster 1 and 4 between 2012 and 2016 (0.467 p. p. in cluster 1 and only 0.01 p. p. in cluster 4). The variability of results is also the lowest in cluster 1 and relatively high in cluster 2 as well as in cluster 3, especially in some years. For Life expectancy at birth (SDG 3), cluster 4 (the best results) and cluster 2 (the worst results) are at opposite ends of the scale in all the years. This means that, on average, the Southern economies showed even higher life expectancies than the cluster 1 countries, including the Northern economies, the Benelux countries, and other developed EU countries. Cluster 1 showed the second highest means in all the years. Except for cluster 3, the values of this indicator increased in all the clusters. However, the value in cluster 3 dropped between 2012 and 2013 and then it slightly increased every year. It was caused by the shifting into cluster 3 of three countries with low life expectancies, namely Lithuania, Hungary and Slovakia. Lithuania showed the lowest life expectancy in the sample in 2013 and the other two countries showed one of the lowest values. The relatively low variability measured by the StD was seen by this indicator, particularly in cluster 1, cluster 4 and cluster 2 (in the latter - except for 2015). In 2015, Lithuania and Croatia returned into cluster 2 and Cyprus and Portugal were included in cluster 2 for one year. The latter two countries have significantly higher life expectancies than the other cluster 2 countries. The mean values of the early leavers (SDG 4) were the highest in cluster 4 in all the years, which indicates the worst results. However, the variability measured by the StD was also relatively high. The best results were achieved by cluster 3 in the first three years and cluster 1 in the latter two years. Thus, these clusters interchanged the best and second best average performance in this indicator. The average values of the indicator decreased in the clusters, except for cluster 2. The highest decrease occurred in cluster 4, which is positive for SD. The significant increase of the mean value that occurred in cluster 2 for this indicator in 2013 and 2014 (see Table 3) is also related to the shifts of particular countries from cluster 2 to cluster 3, particularly the shift of Croatia, Lithuania and Slovakia that showed very low shares of early leavers. As the first two countries returned to this cluster in 2015, the average level declined again. For the SDG 5 indicator, the results are unambiguous again. The highest average employment rates were shown by cluster 1, the second highest by cluster 3 and the lowest ones by cluster 4. There is also a relatively high variability in the indicator values, being the highest in cluster 4 and the lowest in cluster 1. The highest StD value for this indicator across all clusters and over all years was seen in cluster 4 in 2014 and the second highest in the same cluster in 2013. This is because Malta, which had the highest employment rates in all the years, shifted into cluster 4 for these two years. Greece followed by Italy showed the lowest rates in all the years. Spain followed these two with slightly higher rates. Those of Cyprus and Portugal are relatively low as well. For the shares of Population unable to keep home adequately warm (SDG 7), the results are unambiguous as well. The lowest means and the best results are achieved by cluster 1 (with the lowest variabilities in the values), followed by cluster 3, and the worst results by cluster 2 (with the highest variabilities in the values). In 2012, 2014 and 2016, there are only small differences between the average shares of cluster 2 and cluster 4. In 2013, Slovakia, which had a relatively low share, left cluster 2 and the mean value of this cluster increased. There can be more factors behind the changes of these differences. Particularly, Greece showed the highest increase of the SDG 7 indicator in the sample and it currently shows the third highest share. In all the clusters, the mean values dropped in the monitored period, with the most significant decrease occurring in cluster 3 and only a slight one in cluster 1. For the SDG 8 indicator, clusters 1 and 4 are at are at opposite ends of the scale in all the years. Cluster 1 showed substantially lower average rates than the other clusters (above 2%) and the lowest variability in the indicator values. On the other hand, the variability is the highest in cluster 4. Cluster 3 showed lower average rates than cluster 2 in 2012 and in the last two years, but they were slightly higher in 2013 and 2014. In these two years, Croatia that had one of the highest rates was in cluster 3 and Malta that had relatively low rates was in cluster 4 (see Table 2). Except for a slight increase in cluster 1, the average rates decreased in all the clusters, most significantly in cluster 2. For Gross domestic expenditure (SDG 9), clusters 1 and 2 are at opposite ends of the scale, with cluster 1 showing the best results (higher than 2% of GDP) and cluster 2 the worst (lower than 0.8% of GDP). The average shares in cluster 3 were slightly higher than those of cluster 4 every year. The variability of the values for this indicator is the lowest when compared with the other indicators. The highest StD values were shown in cluster 1 (except for 2012). The mean values decreased in all the clusters, which generally does not indicate positive results in relation to SD. For the Gini coefficient (SDG 10), the lowest means and the best results are achieved by cluster 1, apart from the slightly lower coefficient of cluster 3 in 2016. Conversely, the worst results are shown by cluster 2, apart from the slightly higher average coefficient shown by cluster 4 in 2012. The variance was changing. It is the lowest in cluster 2 in 2013 and 2014, when this cluster contained only its core countries (Bulgaria, Romania and Latvia), which all had among the highest coefficients in the sample in all the years. It is the highest in cluster 2 in 2012 and in cluster 3 in the

remaining years. This is especially connected with the shift of Slovakia that had one of the lowest coefficients in the sample. Although those of the CR and Slovenia were also one of the lowest, the third Baltic country, Estonia, had relatively high coefficients in all the years. The variability also remains relatively high in cluster 2 in last two years, when Croatia, which had values around the average levels, shifted back to this cluster. All four Southern countries, along with Cyprus, had relatively high coefficients which were close to one another. This led to the lowest variability in cluster 4, except for 2013 and 2014, when Malta was included in this cluster. The mean values in the monitored period increased in cluster 1 and 2 (adverse development) and decreased in cluster 3 and 4 (positive development).

Resource productivity (SDG 12) had the highest mean values in cluster 1 and the lowest ones in cluster 2 in all the years. These countries are at opposite ends of the scale again. The second highest performance is achieved by cluster 4. Moreover, the average indicator values increased in clusters 1 and 4 over the monitored period. They decreased in the other two clusters, which performed more badly. The variability of the indicator values is generally one of the lowest (along with the SDG 9 indicator). It is the lowest in cluster 2, except for 2015, when Croatia and Portugal, with slightly higher values, and Cyprus, exceeding them more significantly, shifted to this cluster. For GHG emissions per capita (SDG 13), clusters 1 and 2 are at opposite ends of the scale, with cluster 1 showing the worst results (and with the highest variability) and cluster 2 the best (and a relatively low variability). Only in the first year, 2012, did cluster 3 show higher average GHG emissions per capita than cluster 1, but in the next years, emissions were the second highest in this cluster (exceeding 9 tonnes per capita). This is related to the shift of Ireland, showing among the highest emissions in the sample, from cluster 3, and to the shift of the countries with low emissions per capita to cluster 3, especially Hungary, Croatia, Lithuania and Slovakia. The highest average mean and StD value in cluster 2 when compared to the other years is particularly related to the assignment of Cyprus (showing high emissions per capita) to this cluster in 2015. The average emissions increased only in cluster 4 because of their increase in Portugal and Cyprus. For the Corruption Perceptions Index (SDG16), clusters 1 and 2 are at opposite ends of the scale again, with cluster 1 showing the best results and cluster 2 the worst. In 2015 only the lowest average level of the index was shown by cluster 4. In 2015, the three countries showing a higher performance in that year (Malta, Cyprus and Portugal) were not included in cluster 4. However, Cyprus and Portugal returned in 2016. Cluster 3 showed the second best results in all the years. However, it is the only cluster in which the average value of the index declined (the decreases occurred in Hungary and Malta; Ireland having the highest index in this group in all the years shifted to cluster 1). The average shares of environmental taxes (SDG 17) are the highest in cluster 2, except for 2012, when the highest average share was shown by cluster 3. The lowest shares are shown by cluster 1 (with a low level of variability) and the second lowest in cluster 3 (except for 2012). The variability of the values is generally low. The average values increased in clusters 2 and 4 and decreased in the other two clusters. Many of the previously described aspects can be explained in more detail using Figure 4, which displays the mean values of the standardized indicator values over the monitored period. The variability in individual indicator values in cluster 1 over the years is the lowest among all the clusters. This cluster achieved the highest performance in many indicator values and the improvements over time were often slight (in the SDG 3, 7, 12, 13 and 16 indicators) or a slight decrease in performance in some indicator values occurred (in the SDG 1, 5, 8, 9, 10 and 17 indicators). It was either the effect of the economic crisis or, for some indicators, a very high level of performance had already been achieved. The higher decrease occurred only in the SDG 4 indicator, but this was significantly lower than the decrease that took place in cluster 4, which showed the worst results in this indicator. More generally, some trends were identified. Greater improvements occurred in the less developed EU countries; especially those included in cluster 2, as well as those included in cluster 3 and 4 for the selected indicators. Apart from cluster 1, higher differences in the mean standardized values for the indicators between the years were often identified for at least one of the clusters (see Figure 4). Accordingly, convergence may have taken place.

In Figure 4, it can also be seen that cluster 1 and 2 are at opposite ends of the scale for the majority of indicators (the SDG 1, 7, 9, and 10-17 indicators). It is also the case for cluster 1 and 4 for the SDG 5 and 8 indicators, and partly for the SDG 4 indicator, cluster 2 and 4 for the SDG 3 indicator and cluster 3 and 4 for the SDG 4 indicator. Cluster 3 showed the lowest number of values indicating the highest or lowest performance in particular indicators. This occurred for the SDG 4 indicator in the first three years, when this cluster showed the lowest share of early leavers and the best results. Moreover, the lowest mean was achieved for the Gini coefficient in 2016, indicating the highest performance as well. The only sign of the lowest performance were the highest average GHG emissions (the SDG 13 indicator) in 2012. The extreme values in cluster 4 (in Figure 4) are associated with the indicators related to un/employment, education and life expectancy. The lowest mean values of the SDG 5 indicator, the highest values of the SDG 3, 4, and 8 indicators were shown. It means that despite the high average life expectancies, deficiencies were identified in the fields of un/employment, education and in/equality. On the one hand, Spain and Italy showed the highest life expectancies in all the monitored years. On the other hand, these two countries and Portugal showed the highest shares of early leavers. Moreover, all four Southern countries and Cyprus showed as low employment as high unemployment rates (the SDG 5 and 8 indicator respectively). As

Table 4. Assignment to clusters 1 – 4 based on all indicators in the period 2012 – 2016, source: author's calculations

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

Malta left cluster 4 in 2015, the average employment rate significantly decreased and the opposite is true for the employment rate (see Figure 4). This country showed relatively low long-term unemployment rates (the SDG 8 indicator) and even the highest employment rates of recent graduates (the SDG 5 indicator) in all the years. In 2016, changes in opposite directions occurred as Portugal returned and Cyprus shifted to this cluster. This is because these two showed slightly better results than the remaining countries.

4.2 Detailed Analysis of Assignment to Clusters

For the overall assessment, the values of all indicators in all years were used to group the sample of countries into four clusters. In the last row of Figure 2, the corresponding dendogram is displayed. Table 4 shows the assignment to clusters resulting from Figure 2 in accordance with the values of the twelve indicators. The assignment is clear in the case of those countries which were included in the same cluster in all the monitored years. This is the case for all cluster 1 countries. On the other hand, Ireland, which shifted to cluster 1 for the latter three monitored years, is assigned to cluster 3 according to this evaluation based on all indicator values. As regards the other countries, which changed their cluster assignment, Croatia, Lithuania and Hungary belong to cluster 2, Slovakia to cluster 3, and Cyprus, Malta and Portugal to cluster 4. The rationale behind these assignments also results from Figure 3, where each group is seen, including the shifts of countries over time. Although Hungary and Slovakia experienced the same shifts between clusters (see Table 2), they are assigned to different clusters based on all indicator values. It can be seen in Figure 3 that Hungary remained closer to cluster 2 countries than Slovakia.

The assignment of Portugal is clear; it extraordinarily changed its position and moved closer to cluster 2 countries in 2015. This is the year in which this country significantly improved its performance in both indicators related to un/employment. However, the most ambiguous positions are those of Malta, Cyprus and Ireland, which could also create a separate cluster according to their positions in Figure 3. Moreover, Figure 2 shows that their positions changed markedly. Ireland, which was closest to Estonia and Poland (2012) and also close to Cyprus (2013), was closest to the UK from 2014 and also the Netherlands in the last two years. Accordingly, the shift of Ireland towards the group of cluster 1 countries is unambiguous. Malta and Cyprus were closest together in 2012. However, Malta then shifted to cluster 4 and was closest to the Southern countries, especially Italy, while Cyprus remained closest to Estonia and Ireland in cluster 3 (2013). The position was the same in Malta in 2014 and Cyprus shifted closer to Croatia in cluster 3 (see also Figure 3). In the following year, Malta shifted into cluster 3, but it did not form a close group with any countries. In 2015 Cyprus moved to cluster 2 along with Portugal and they became the close pair of countries showing highest similarities. Finally, Cyprus had the closest linkage with Portugal in cluster 4, while Malta remained in the similar position as in 2015.

As Figure 2 indicates, there are often closer linkages between the countries that are somehow interlinked. Generally, the Northern countries, the Southern countries and some transitive countries created closer groups, but it is not the case for all three Baltic countries. Concerning the Benelux countries, Luxembourg was often separated in cluster 1. Croatia showed remarkable development from being closest to Slovakia in 2012 (in cluster 2), to being close to other transitive countries and even Cyprus and Portugal as well as Latvia. Figure 3 records these changes in more detail. The trend of development can generally be interpreted as a convergence of the less developed countries to the more developed cluster 1 countries. This can especially be seen in the case of Ireland, which was already included in cluster 1, and the CR and Slovenia (with some reversed trends in the second country), which were already close to cluster 1. Slovakia, Poland, Latvia, Portugal and Croatia also showed clear trends of convergence, although they started in different positions. Conversely, some reversed trends can especially be seen in the case of the other two Baltic countries, while Lithuania also returned to the less developed cluster, cluster 2. Similar trends were also seen in two small countries, Malta and Cyprus, which experienced many changes. Malta has already shown the direction towards cluster 1 countries within cluster 3. On the other hand, Cyprus behaved erratically, moving from cluster 3 to cluster 2, and ending up in cluster 4. The remaining three Southern countries also showed some reversed trends, but recently they seem to have moved towards cluster 1 countries. The development of the two least developed countries, i.e. Bulgaria and Romania, is not quite clear, or at least the convergence seems to be slow. Moreover, in Bulgaria the shift closer towards cluster 4

countries is also possible. The effects of the economic crisis also caused many of the negative trends in the development of the indicators related to sustainability and SD.

It can be concluded that the extent of similarities and linkages is often determined by common history, location (boundaries) and features of the economy. Moreover, convergence towards the more developed countries has been taking place. However, the majority of countries were also negatively affected by the economic crisis. The cluster 3 countries seem to be in the best position to converge towards cluster 1 countries. The aspects evaluated in the following two subsections further explain the rationale behind the linkages between the countries and their changes.

The development of the indicator values determines the composition of the clusters and the changes in their composition. In the whole sample, the average values of the SDG 1, 4, 7, 8 and 13 indicators decreased (the latter only very slightly). This is positive for sustainability. The value of the SDG 9 indicator also decreased, which is negative for sustainability. Conversely, the average values increased for the SDG 3, 5, 12, 16 and 17 indicators, which is positive for sustainability, and for the SDG 10 indicator, which is negative for sustainability. Accordingly, the changes can indicate a shift towards/from the path of SD.

4.3. Evaluation and summary

When comparing the results of this work with those included in the literature review, many similarities can be seen. A high performance of the Northern countries and a poor performance of cluster 2 countries and the Southern countries were often confirmed. Allievi et al. (2011) emphasised the performance of Latvia and Cyprus, but it was only in particular dimensions of SD, i.e. in the environmental in the first and in the social in the second country. However, SD is based on a high performance and balance between all three pillars along with the institutional dimension. In this work the high performance of Latvia in the relevant dimension would be especially related to one of the lowest GHG emissions per capita and the highest share of environmental taxes in the sample[3] (the SDG 13 and 17 indicators respectively) and in the case of Cyprus to high Life expectancy at birth (the SDG 3 indicator). However, they both showed deficiencies in many areas of sustainability, including the institutional dimension. There are some differences in the assignments to clusters from the work of Huttmanová (2016). Nevertheless, several countries among which close linkages were identified are in common clusters in this work as well. Particularly, three Northern countries analysed and the majority of transitive countries formed common clusters. However, other countries were included as well. Drastichová (2017) also showed that the application of different indicators can lead to quite different results. The Northern countries, Germany and Austria formed a common cluster as well. However, the other countries included are five transitive countries, namely the four core cluster 3 countries from this work and Lithuania. The important feature of this group was the low level of environmental wellbeing and a relatively high economic and human wellbeing. The remaining cluster 1 countries from this work formed cluster 2 with Italy, Spain and Switzerland and the important feature of their similarity was the high level of RP (the SDG 12 indicator). The remaining transitive countries, Malta, Cyprus, Ireland and two Southern countries (Portugal and Greece) were grouped together in cluster 3, which was characterised by low average economic and human wellbeing as well as RP, but high environmental wellbeing. These results are quite different, but depend on the methodology and the sub-indices used. Drastichová (2018a) used similar nine indicators to those included in this analysis and similar four clusters were constructed using the data of 2007 and 2016. The composition of cluster 1 is similar to that in this work, but it also includes Switzerland and, moreover, Slovenia shifted to this cluster in 2016, which was evaluated as a significant shift towards SD. However, Ireland shifted from cluster 4 to cluster 3 between 2007 and 2016. The three core cluster 2 countries from this work were included in cluster 2 in 2007 as well. However, only Lithuania was included in this cluster with them and it remained there in 2016, while Latvia shifted to cluster 3 and Romania to cluster 4. The latter confirms the trend indicated in Figure 3 that the least developed countries, Bulgaria and Romania, can move closer towards cluster 4 countries. When compared to this work, Croatia, Slovakia and Hungary are included in in cluster 3 in both years and in 2016 Slovenia shifted to cluster 1. Malta was included in cluster 4 with four Southern countries in both years and Romania and Cyprus shifted there in 2016 from clusters 2 and 3 respectively. The results of Halasková (2015) are in compliance with the findings of this work. The Northern countries along with other developed countries showing high R&D expenditure created a common cluster. Moreover, Slovenia showed a relatively high expenditure and in the more recent period it was included with these countries as well. Based on Drastichová (2018a) Slovenia has already shown a number of similarities to cluster 1 countries. This is also confirmed by Drastichová (2018b), where the Northern American

[3] Only in 2012 Latvia was slightly surpassed by Slovenia.

countries were also included in the analysis. In this work, not only Slovenia and Ireland, but also Lithuania created a common cluster, cluster 1, with the Northern countries, Austria and Switzerland. The high performance of Lithuania in that analysis was significantly related to its high education expenditure. On the other hand, Estonia and Luxembourg were in a common cluster, cluster 3, only with the USA and Canada, which all had poor results in the environmental dimension of SD.

Following a detailed review of the development in indicator values, a final assessment of eight countries that changed cluster assignments between the years is provided. The SDG 1 indicator increased only in Cyprus. Portugal showed the lowest increase of the SDG 3 indicator among them. Slovakia and Hungary showed increases in the SDG 4 indicator. Although Slovakia showed the highest increase in the sample, the share is still below the average of the sample. The SDG 5 indicator increased in all of them, but that of Cyprus was very low. The SDG 7 indicator decreased in all of them. The lowest decrease was in Slovakia, followed by Croatia. The SDG 8 indicator declined in all of them, except for Cyprus, while the highest drop was shown by Ireland, followed by Slovakia. For the SDG 9 indicator, drops occurred in almost all these countries, apart from Croatia and Cyprus. In Hungary, Cyprus, Malta and Lithuania, the SDG 10 indicator values increased. Lithuania showed the highest increase in the sample and Croatia one of the lowest decreases. The SDG 12 indicator also decreased in the majority of them, except for Ireland, which showed the highest increase in the sample, as well as Cyprus and Portugal. Ireland also showed the highest increase of the SDG 13 indicator and it was directly followed by Cyprus and Portugal and emissions also increased in Hungary. Cyprus showed the highest decrease of the SDG 16 indicator in the sample. The decrease was also high in Hungary and slight in Malta and Portugal. High increases were shown by Slovakia and Lithuania. The SDG 17 indicator declined in Ireland, Slovakia and Malta and the highest increase was shown by Croatia.

The following summary is focused on the evaluation of the path towards SD.[4] Special attention is paid to the countries that changed clusters over time. Slovakia and Hungary showed similar developments in the majority of indicators. Although it showed some negative trends and weaker progress in several indicators, especially those related to un/employment, the position of Slovakia in cluster 3 is justified. The most crucial features of the negative development in Hungary was the significant decrease of the Corruption Perceptions Index (and also the slight increase of the Gini coefficient), which can shift this country closer towards cluster 2 countries again. Croatia, Latvia and Lithuania predominantly achieved significant progress towards higher sustainability. Lithuania even showed the second highest performance in the SDG 4 indicator, following Croatia, and it is better off than Slovakia in both indicators related to un/employment. Overall, Lithuania and Croatia, along with another cluster 2 country, Latvia, showed significant progress. However, the factor that shifted Lithuania closer towards cluster 2 countries again was the significant increase of the Gini coefficient (the SDG 10 indicator). Apart from the slight decrease in performance in the SDG 12 indicator in Lithuania and Croatia, the SDG 13 indicator in Latvia and the SDG 9 indicator in Latvia and Lithuania, no other deterioration was identified. There is also another important factor in similarities between the cluster 2 countries, which is the high share of environmental taxes. This moved especially Croatia closer towards cluster 2 countries again (with the fifth highest share in 2016).

The remaining two cluster 2 countries predominantly showed poor results in the indicators included. Moreover, in a number of indicators they showed significant similarities with Greece. Accordingly, a shift towards cluster 4 countries could be expected in the future. Significant differences only exist in the SDG 3, 4 and 12 indicators, where Greece had much better results. On the other hand, Greece showed much higher long-term unemployment rates (the highest level of the SDG 8 indicator in the sample in each year) and higher GHG emissions per capita (which were one of the lowest in the sample in Romania). The shares of environmental taxes (the SDG 17 indicator) of Greece and Bulgaria were one of the highest in the sample in each year and Romania showed a high increase. Despite the poor results, the progress was often slow in these countries or even deterioration occurred, especially in Greece (such as in the SDG 1, 7 and 8 indicators in Greece, the SDG 4 indicator in Bulgaria and Romania, and the SDG 5 indicator in Romania). The Gini coefficient was one of highest in the sample in all of them and the increases occurred (that of Greece did not change in the monitored period). It can be claimed that these are the worst performing countries of the sample.

Although the shifts of both Malta and Cyprus to cluster 4 are associated with substantial increases in their life expectancies, the negative features of development also occurred in both of them. As regards Cyprus, besides a slight increase in the SDG 1 indicator, relatively high increases in the SDG 8, 10 and 13 indicators, and the highest drop in the SDG 16 indicator in the sample, shifted this country not only closer to cluster 4 countries, but towards lower sustainability as well. Besides high levels of the SDG

[4] When the performance in indicators is evaluated without indicating a particular year, the most recent year, 2016, is used.

3 indicator, Malta was in cluster 4 particularly due to having one of the highest shares of early leavers in the sample and a relatively low Corruption Perceptions Index, while its performance in the un/employment indicators and the Gini coefficient is much higher. This is also the case for the SDG 1 indicator. Despite worsening its performance in the SDG 9, 10, 12, 16 and 17 indicators, significant improvements were also achieved in the SDG 1, 3, 7 and 13 indicators.

Ireland also faced a decrease of its performance in several indicators. However, its development can be evaluated as clearly closer towards SD, because it also shifted to cluster 1, which showed the highest average performance. Although without a shift into cluster 1, but based on their position and the results of analyses (including previous studies), the other two countries with a substantially positive development are the CR and Slovenia (a decrease in performance was only seen in the SDG 4, 9 and 10 indicators for both, and for the CR also in the SDG 17 indicator). Although some reversed trends were seen in Slovenia (Figure 3), the progress and positive development of this country can be confirmed. The position of other two cluster 3 countries, Estonia and Poland, is further from cluster 1. The development of Poland was predominantly positive (only its GHG emissions did not change).

Some reversed trends were seen in Estonia (worsening of its performance in the SDG 1, 4, 10 indicators and most significantly in the SDG 9 indicator). It can be claimed that Sweden is the best performing country of the sample. Although Norway showed one of the highest performances in most indicators (the SDG 1, 3, 5, 7, 8, 10 and 16), the results of Sweden were more balanced. Moreover, Sweden showed the second lowest GHG emissions per capita in the sample in 2016, while those of the other Northern countries are significantly higher. Sweden is also a leader in the SDG 9 indicator. On the other hand, Norway showed a relatively low performance in the SDG 4 indicator. Although both countries had relatively low shares of environmental taxes, the other features of taxes are important as well. For some indicators, the progress slowed down or the situation worsened in these as well as in other cluster 1 countries. Figure 3 showed that these countries placed in the very left part did not have a clear trend of development or some shifts (often slight) in the opposite direction were shown. This could also have been elicited by the effects of the economic crisis. The majority of other countries that showed progress shifted closer towards them. In terms of cluster 1, this was also the case for Belgium, the UK and France that moved closer to the remaining countries. It can be seen in the case of the SDG 1 and 7 indicators, which decreased in Belgium, France and the UK, but increased in several other cluster 1 countries, including Norway and Sweden. In all three countries the SDG 9 and 12 indicators increased (despite many drops that occurred for the SDG 9 indicator) and the SDG 13 indicator decreased. In France and Belgium the SDG 10 indicator decreased as well.

5. Conclusions

The aim of the paper was to cluster the sample, which includes the 28 EU countries and Norway, according to their sustainability levels, to evaluate the extent of sustainability of the created clusters and to discover if shifts closer towards the path of SD took place. Selected indicators included in the EU SDG indicator set were used to measure sustainability and their change in the period 2012 – 2016 to reflect SD.

Overall, cluster 1, which includes the Northern countries, the Benelux countries, Germany, Austria, France, the UK, as well as Ireland (from 2014 onwards), is evaluated as the best performing cluster in relation to the examined indicators. Cluster 2, which includes three core countries each year (Bulgaria, Romania and Latvia), is evaluated as the worst performing cluster. Slovakia, Hungary, Lithuania and Croatia were also included in 2012. Only Lithuania and Croatia returned to this cluster (in 2015). Cyprus and Portugal were included in cluster 2 in 2015, forming the closest linkage within this cluster.

Cluster 3 includes the transitive economies – the CR, Estonia, Slovenia and Poland in each year, along with Slovakia and Hungary, which shifted there from cluster 2 in 2013. Cyprus was included in the first three years and Malta in 2012, 2015 and 2016. The core countries of cluster 4 are four Southern countries. Although Portugal shifted to cluster 2 for one year, this country belongs to cluster 4. Cyprus is a cluster 4 country according to all indicator values as well, although it moved into this cluster only in the last monitored year, 2016. Malta is also a cluster 4 country according to all indicator values. However, it shifted to cluster 3 in the last two years. This country showed significantly better results in un/employment indicators (the SDG 5 and 8 indicators). It is likely that this country has shifted and can also move closer towards the cluster 3 countries in the future.

Although cluster 4 showed the highest average performance in Life expectancy at birth (the SDG 3 indicator) in all the years, even exceeding the values of cluster 1, the opposite extreme is shown in the indicators representing education (the SDG 4 indicator), un/employment (the SDG 5 and 8 indicators) and equality (the SDG 10 indicator in 2012). In several indicators (the SDG 1, 9, 10, 16 indicator), at least for several years the second lowest performance was shown. Cluster 3 showed the highest average performance only in the shares of early leavers (the SDG4 indicator) in the first three years and in equality (the SDG 10 indicator) in 2016. Alt-

hough it was surpassed by cluster 4 in Resource productivity and GHG emissions (cluster 4 had higher performance in the SDG 12 and 13 indicators), cluster 3 showed the most balanced results. Except for the SDG 13 indicator in 2012, the lowest performance was not identified. Therefore, cluster 4 is evaluated as the cluster with the second lowest performance and cluster 3 as the cluster with the second highest performance in sustainability. The worst performing cluster, cluster 2, showed the highest average shares of environmental taxes in total tax revenues in 2013-2016 (the SDG 17 indicator). This could help these countries move closer towards the path of SD in the future by means of the application of the principle of revenue neutrality. The lowest average performance of cluster 1 was only identified in the case of GHG emissions and environmental taxes (the SDG 3 and 16 indicators). Accordingly, in the particular aspects of sustainability measured by particular indicators, the worse performing clusters also showed a high performance. Conversely, cluster 1 did not show the highest performance in all the aspects included. Nevertheless, the path of SD is understood as a high level of performance in all the pillars, or at least a balance between them. Therefore, clusters showing significant deficiencies in several indicators (areas of sustainability) are not sustainable.

As regards the evaluation of the whole sample, not all the indicators developed towards the path of SD. Decreases in the average values of People at risk of poverty or social exclusion, Early leavers from education and training, Population unable to keep home adequately warm, Long-term unemployment rate, and Greenhouse gas emissions per capita (the SDG 1, 4, 7, 8 and 13 indicators, the latter only very slightly) can be understood as shifts towards higher sustainability. The value of Gross domestic expenditure on R&D (the SDG 9 indicator) decreased as well, which can undermine the path of SD, as this indicator can affect all the dimensions of SD. The increases in average values of Life expectancy at birth, Employment rates of recent graduates, Resource productivity, Corruption Perceptions Index, and Shares of environmental taxes (the SDG 3, 5, 12, 16 and 17 indicators), should lead to higher levels of sustainability. On the other hand, the increase in the Gini coefficient (the SDG 10 indicator) led to lower equality and lower performance in relation to sustainability. Overall, the average values of the majority of indicators developed in the right direction, but it is not always the case for particular clusters. Moreover, the development of the R&D expenditure and the Gini coefficient is challenging in relation to SD, as the values developed in the wrong direction in many countries.

Sweden was evaluated as the best performing country and Norway as the second best. Greece, Bulgaria and Romania are the countries showing the poorest performance. When assessing the trend in development in the whole sample by a division into clusters, a trend in changes towards eight cluster 1 countries was identified. These are the Northern countries, two Benelux countries, Germany and Austria. The remaining cluster 1 countries, i.e. Belgium, France and the UK, and the countries from other clusters often converged towards them, depending on their ability to achieve progress.

Concerning particular countries in relation to their assignments to particular clusters and their changes, Ireland is evaluated as the country that shifted towards the path of SD most significantly. This country shifted into cluster 1 in 2014, completing the group of the most developed EU countries. Moreover, another two countries, the CR and Slovenia, are emphasized as those being close to the cluster 1 countries and those that have developed the most towards higher sustainability (with some reversed trends in the second one). The shift of Slovakia and Hungary into cluster 3 in 2013 can also be evaluated as a shift towards higher sustainability levels. However, a great challenge for Slovakia is to improve its performance in the indicators related to un/employment (the SDG5 and 8 indicators). Although Hungary showed the higher performance in these indicators, it still has many other deficiencies in which it is also similar to cluster 2 countries. Croatia and Lithuania shifted back to cluster 2 after moving to cluster 3. However, especially Croatia showed significant progress in many indicators. Both Croatia and Latvia showed significant shifts (convergence) towards cluster 1, but they still have a long way to go to achieve a sufficient performance in many indicators. That is also the case for Poland and Portugal. The development of Cyprus can be evaluated as the clearest example of the path towards higher unsustainability (moving in a circle, ending further from cluster 1). Negative trends of development were also identified in Lithuania and the remaining cluster 4 countries. However, all of them seem to be finding the right direction after showing some reversed trends in their development. These could predominantly be caused by the effects of the economic crisis. On the other hand, the least developed cluster 2 countries, Bulgaria and Romania, could continue in the trend of development towards cluster 4 countries.

An important challenge for further analysis is to improve the methodology for the measurement of SD, i.e. changes in sustainability, based on as many crucial indicators representing the pillars of SD as possible, simultaneously allowing for a detailed assessment of each dimension of SD as well as each indicator.

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