The indicator-based measurement of the circular economy in the countries of the European Union

A körforgásos gazdaság indikátoralapú mérési lehetőségei az Európai Unió országaiban

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ABSTRACT: The circular economy, as a new economic model, is an integral part of sustainable development and the opposite of the linear economy that still exists today. In terms of its basics, it is a sustainable economic system in which economic growth is absolutely decoupled from the use of resources in order to reduce the use of the latter and recycle them. In the present study, the authors describe the possibility of measuring the circular economy and establishing a ranking for the 28 Member States of the European Union based on composite indicators. The values of the CCEI index thus created are compared with rankings produced by other researchers in similar and different ways, so the suitability of the method is based on its comparability.

The primary objective of the study is to describe the creation of composite indicators and to analyse their comparability. A further aim is to characterise the leading and the tail-end countries from which conclusions can be drawn regarding ranking, and thus make them comparable. The research objective is achieved by using secondary data collected by Eurostat for the year 2018. The indicators of the circular economy were grouped according to four areas: production and consumption, waste management, secondary raw materials, and competitiveness and innovation. These areas adequately illustrate topics related to the circular economy.

In terms of its structure, the international literature related to the circular economy is reviewed first, followed by the EU strategy, and sets of relevant indicators. In the methodological chapter the methodology of the analysis, the scale alignment transformation, is explained. A comparison is then made from composite indicators using rank correlation, and conclusions follow.

The research findings of the study highlight the fact that composite indicators can be created in relation to the circular economy; however, creating and comparing them is not an easy task. The rankings on which the comparison is based show a very high degree of similarity with other selected rankings. Overall, states such as Germany, the

United Kingdom, the Netherlands, and Italy are almost without exception at the top of the rankings, while the group of tail-enders is led by Malta and Estonia. Based on the results of the macro-level studies, the authors establish a kind of competitiveness ranking.

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KULCSSZAVAK: körforgásos gazdaság; Európai Unió; skálaösszehangoló transzformáció; rangsorok

ABSZTRAKT: A fenntartható fejlődés részét képező körforgásos gazdaság teljesen ellentétes a lineárissal. A koncepció lényege egy fenntartható gazdasági rendszer, ahol a gazdasági növekedés során hatékonyabb, racionálisabb az erőforrások felhasználása és újrafelhasználása. Tanulmányunkban a körforgásos gazdaság kompozit indikátorokkal való mérési lehetőségét mutatjuk be az EU 28 tagországára vonatkozóan. Az előállított CCEI mutató értékeit összehasonlítottuk más kutatók hasonló vagy eltérő módon előállított rangsoraival. A kompozit mutatók jóságával és egyszerűségével a hasonló kutatási eredmények, rangsorok kiválóan vizsgálhatók.

Tanulmányunk elsődleges célja a kompozit indikátorok létrehozása, összehasonlítása. További célkitűzése az élen járó és sereghajtó országok jellemzése, amelynek alapján következtetések vonhatóak le a rangsorban való elhelyezkedésre, és ezáltal összehasonlíthatóvá válnak. A kutatási cél megvalósítása szekunder adatok segítségével, az Eurostat különböző, a körforgásos gazdaság valamely részterületéhez kapcsolódó adatbázisán alapul a 2018-as évre vonatkozóan.

A tanulmányban elsődlegesen a körforgásos gazdasághoz kapcsolódó nemzetközi szakirodalmat, majd az EU-t jellemző stratégiát és a releváns mutatószámok készletét tekintjük át. A módszertani fejezetben az elemzés módszertanát, a skálaösszehangoló transzformációt fejtjük ki. A kutatási eredményekben összehasonlítjuk a más szerzők és a magunk által kidolgozott, kompozit indikátorokból létrehozott rangsorokat rangkorreláció segítségével, majd ezt követik a következtetések.

A kutatási eredmények arra engedtek következtetni, hogy az összehasonlítás alapját képező rangsor többségében (néhány kivételtől, például Németország, eltekintve) nagymértékű hasonlóságot mutat a kiválasztott rangsorokkal szemben. Összességében megállapítható, hogy a legtöbb esetben Németország, az Egyesült Királyság, Hollandia és Olaszország vezetik a rangsorokat, és a sereghajtó országok, mint például Málta, Észtország, is hasonlók.

Introduction

There is a long history of trying to identify and address the unsustainable processes that are closely linked to human activities. The impact of these processes and the explosion in population growth are drastically reducing the available resource base, which runs counter to the concept of sustainability. In contrast to sustainable development, the history of the circular economy dates back to the 1960s, when it entered into the economic, social, political and

cultural mainstream (Korhonen, Honkasalo, Seppälä 2018). Pearce and Turner (1990) were the first to use the term to describe an economic model based on the first two laws of thermodynamics. Walter R. Stahel, on the other hand, locates the theoretical foundations and approach of the circular economy in the 1980s (Stahel 2019).

In recent decades, the idea of shifting from a linear to a circular economy has received increasing attention worldwide, including in the European Union, with one of the main goals being to break away from an unsustainable production and consumption model and adopt a circular economy. According to García-Barragán, Eyckmans and Rousseau (2019), a global trend is that international communities are exploring potential pathways for transitioning. Going back to the concept of sustainable development, the circular economy model has been widely researched as a potential means of creating a sustainable economy (Janik, Ryszko 2019).

It is only in recent years that the results of studies and research on the circular economy have become known in which similar research was carried out (and the authors of this study have taken part in, too). However, measuring progress in terms of the related performance and comparing and contrasting this is as difficult a task as getting different countries to fully adopt a circular economy approach. In line with claims by Elia, Gnoni and Tornese (2017), the research on indicators and metrics that measure the level of implementation of circular economy strategies is still at a relatively early stage. In this paper we aim to compare the rankings created by the present authors with those of other researchers, and to see how they agree or differ in the method of creation, the indicators and the final rankings.

In terms of the structure of the paper, the definition, the concept and the objectives of the circular economy are first presented, followed by research results from the relevant international literature. Finally, the indicators underlying the composite indicators are defined. In the methodological chapter, the methodology used for the analysis, the scale alignment transformation, and the results of the studies on which the comparison is based are presented. This is followed by a discussion of the research results and their implications and the conclusions that reveal the scientific and practical utility of the research results, as well as related difficulties and future research opportunities.

The Circular Economy in General, and in the Case of the European Union

Since the Second Industrial Revolution, production processes have typically been linear, while the circular model is based entirely on circular flows. The traditional linear path pursues economic growth in a way that is detrimental to environmental and social equilibrium (Horváth 2019). In contrast, in a circular

economy, the manufature of products, their transport, and other processes require much less raw material and the amount of waste that is generated is much less. The transition from a linear to a circular economic model requires different strategies at the city, regional, national and global level (Vanhamäki et al. 2020).

According to the Ellen MacArthur Foundation, the transition requires adhering to three principles: 1) preserving and enhancing natural capital by controlling finite stocks and balancing the flow of renewable resources; 2) optimising resource returns to achieve the highest utility at any given time; and, 3) promoting system efficiency by identifying negative externalities (The Ellen MacArthur Foundation 2013). In recent times, business, politicians and other advocates have increasingly been calling for a shift from a linear to a circular model as a radical and transformative solution to the currently unsustainable linear economy (Merli, Preziosi, Acampora 2018). Looking into this "shift", it can be seen that the linear economy does not totally ignore the environmental impacts of using resources and disposing of waste, that results in the consumption of too many resources. In contrast, the circular economy takes into account the impact of resource consumption and waste on the environment (Sauvé, Bernard, Sloan 2016).

Defining the Circular Economy

The circular economy, as the Ellen MacArthur Foundation describes it, "is an industrial system that is restorative or regenerative by intention and design. ... It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (The Ellen MacArthur Foundation 2013, 7.). The model involves a systems-thinking approach which is highly open-ended due to its characteristics, thus supporting the economic, social and environmental dimensions of sustainable development, with which it is in close synergy (Robinson 2021). While there are many definitions of the circular economy (CE), most of them are concerned with describing the processes of value preservation (Nasr et al. 2018). In their review of the literature, Niskanen, Anshelm and McLaren (2020) also refer to the definition of the Ellen MacArthur Foundation. Robaina et al. (2020) describe CE "as an economic system in which the value of products, materials and resources is maintained in the economy as long as possible and the quantity of waste is minimised" (Robaina et al. 2020, 2.). As a principle, it refers to an economic concept that, according to Fogarassy and Horváth (2018), "separates growth and development as a global model, taking into account the finite resources of

consumption systems. It uses a restorative design process to keep products and their components at their highest level of use and value" (Fogarassy, Horváth 2018, 4.). The European Commission defines the circular economy as "one in which the value of products, materials, and resources is maintained for as long as possible, minimizing waste and resource use" (European Commission 2015, 21.). The circular economy, also known as the cradle-to-cradle model, always goes beyond recycling waste, as it seeks to minimise negative environmental impacts by closing material cycles (McDonough, Braungart 2002). The common feature of the concepts is that in all cases the circular economy is seen as a system wherein materials and resources take part in processes for as long as possible and are maximised and maintained at their highest use value and level.

Companies, academics and consumers have used various formulations and proposals to measure the circulation of services and products (Corona et al. 2019). In a study, Kirchherr, Reike and Hekkert (2018) identified and analysed a total of 114 definitions that describe the circular economy that refer to the 3Rs (reuse, reduce, recycle), the foundations of the circular economy model. The most commonly found conceptualisation of the circular economy is that it is an economic system based on a business model that replaces the "end of life" concept by reducing, and alternatively using, recycling, and recovering materials in the processes of production, distribution, and consumption. The impact of these activities is to improve waste management and thereby reduce the negative impacts, in environmental terms, of sustainable development (Costa, Massard, Agarwal 2010).

The above-mentioned 3Rs that are associated with circular economy are the basis of the concept. According to some authors, such as Winans, Kendall and Deng (2017), the circular economy not only consists of the 3Rs, but is complemented by three more elements (redesign, remanufacture, and recover) and includes, in addition to these factors, zero emissions, resource efficiency and life cycle analysis (LCA). Finally, Potting et al. (2017) extends the 6R to 9R by adding refuse, refurbish, and repurpose.

Four main bases for the implementation of CE can be distinguished. The first relates to the economic planning process, which focuses on a life-cycle approach and stresses the importance of circularity (Nemes 2018). Business model innovation is the second base, in which innovative and new business models are introduced that are mutually beneficial (Fogarassy, Horváth 2018). The third base is maximising waste reduction and extending the life cycle of manufactured products (Morseletto 2020). The fourth and last base is creating the most favourable business, environmental, and system-level incentives (Nemes 2018).

Looking at the objectives of the circular economy, Horváth (2019) formulates the primary objective "as the need to enforce the functioning of natural ecosystems in economic systems, which requires the use of resources consumed

by economic activities in a closed economy" (Horváth 2019, 16.). A further objective is reduc[ing] resource use by slowing, narrowing and closing resource loops (Wang, Kara, Hauschild 2018). Mayer et al. (2018) identify maintaining the value of products, materials and resources for as long as possible as the fundamental goal of a circular economy, in which waste is minimised. Janik and Ryszko (2019) formulate the goal of the model as the continuous maintenance of the highest value and utility of products and components.

According to Lieder and Rashin (2016), the benefits of the CE include minimising environmental externalities, stimulating the innovation process, creating new jobs where possible, saving energy and materials, reducing the price of raw materials, creating a more sustainable economy, and increasing international competitiveness. CE can make companies aware of the need to optimise material and energy flows. Among the benefits, Ethirajan et al. (2020) list the preservation and enrichment of natural capital and the minimisation of systemic risk. A criticism of the model is that it is considered to be insufficiently scientifically sound, as attempts were made to put it into practice almost immediately after its publication. Another limitation is related to its spatiality. Different social and economic geographies can have a decisive impact on where and how sustainability and circularity can be achieved and on the internal dynamics within a large community such as the EU (Nemes 2018).

The Circular Economy and the European Union

On 2 December 2015, the European Commission launched an Action Plan for the transition to a circular economy (Circular Economy Action Plan – CEAP), which is also an integral part of the Seventh Environmental Action Programme (Pomázi, Szabó 2018). It focuses on high-level EU action and on building a low-carbon, competitive, sustainable and resource-efficient economy (COM/2020/98) (European Commission 2020). Its main objective is to make the EU more productive regardless of the requirement of using fewer resources and thus freeing up potential (Amanatidis 2019). It also aims to create new jobs, improve global competitiveness, and stimulate sustainable economic growth (Momete 2020).

Further economic growth and implementing the elements of the circular economy are prerequisites for the harmonious development of the European Union. The circular economy will boost EU competitiveness by protecting businesses from resource scarcity and volatile prices, and by helping to create new business opportunities and innovative, more efficient ways of producing and consuming. It can create jobs at the local level and offers opportunities for social inclusion and cohesion. Action at the EU level will guide investment and create a level playing field (European Commission 2018). By encouraging sustainable activity and new business opportunities in key sectors at the Member State level

and within the V4, the plan will help unlock the growth and jobs potential of the circular economy.

The European Commission recognises the need for change and that CE requires systemic change, taking into account the myriad of links between sectors and within and across value chains. Overall, the CEAP contains 54 measures related to circular policy, which focus on different interpretations of the principles related to waste management (European Commission 2019a). In addition, it includes four other legislative proposals – on waste, landfills, packaging, and end-of-life vehicles and batteries (Amanatidis 2019). By 2030, the European Union has defined the following key goals in relation to the circular economy: a decrease of 70% of packaging waste, 60% of municipal waste, and reducing the waste that goes to landfill. According to the newly updated CEAP in 2020, the European Union will provide a future-oriented agenda for a more competitive and cleaner Europe, based on a circular economy, in close cooperation with citizens and economic and civil society organisations. It aims to accelerate the change required by the European Green Deal, while building on the circular economy measures implemented since 2015 (European Commission 2021).

The Member States have increased their efforts to implement the circular economy model in order to facilitate changes in the labour market and business models. Their aim is to establish new business models and open up new opportunities for resource reduction, recycling, and reuse (Marino, Pisano 2020). Looking at the three dimensions of sustainable development, the main potential gains from the circular economy model can be summarised as follows. In the social dimension, there will be an increase in cooperation in community processes, more conscious consumer attitudes, and growth in social capital. In the environmental pillar, less resource use, greater resource efficiency, and fewer harmful emissions are expected, while in relation to the third and last dimension, the economic perspective, waste management costs will be lower, new economic activities and forms of employment will be created, and last but not least, depreciation and pollution costs will be reduced (Nemes 2018).

Empirical analysis

Monitoring frameworks and evaluation systems are essential for supporting progress towards the circular economy. While the concept of circularity has been extensively studied and numerous case studies have analysed its application in different contexts, Haas et al. (2015) argue that the tools for measuring the circularity of countries and regions remain limited. Nevertheless, there is a consensus about the need to use measurement instruments to manage the transition at a systemic level. Indicators of circulation have been developed over time (Saidani et al. 2019). These indicators are structured at three levels: macro

(global, national, regional), meso (industry symbiosis), and micro (single firm, single product). Kristensen and Mosgaard (2020) have also demonstrated the need for indicators that are essential for analysis, which can also be identified in relation to the various strategies of larger cities or countries.The publications of numerous authors were investigated and the conclusion established that a significant number of them refer to three forms of analyses which can be said to provide an almost comprehensive picture of the mapping of indicators associated with the circular economy. However, Elia et al. (2017) conclude that none of the indicators or environmental assessment methods that are reviewed can meet all five requirements, or be successfully used to monitor activity. According to Parchomenko et al. (2019), landfilling, the primary or secondary use of resources, resource efficiency/productivity, and recycling efficiency were the most typical CE elements covered by the indicators they reviewed. Furthermore, regardless of the fact that a central element of the circular economy is value preservation (highlighting the need for the preservation of natural assets), few indicators address this (Parchomenko et al. 2019). Based on the work of Saidani et al. (2019), it can be concluded that indicators have a supporting role and that further evaluation of existing indicators is needed to provide a greater sense of security in terms of use.

In addition to the three major studies presented above, other studies present the problems and difficulties of measuring the circular economy with indicators. In their research, Ghisellini, Cialani and Ulgiati (2016) reviewed 155 studies, of which only ten focused on the design or discussion of indicators for evaluating CE strategies, despite the strategic importance of evaluation and monitoring tools that can highlight the shortcomings of the circular economy. This conclusion can be found in Kristensen and Mosgaard (2020), but further parallels can be found regarding the gaps in indicators. The early stage of development of indicators was also highlighted by Giurco et al. (2014).

Analyses and studies at the micro level are in their infancy, as evidenced by the work of Linder, Sarasini and van Loon (2017). In Europe, the focus on indicators is attracting attention, especially at the macro level, where common guidelines for the application and measurement of CE strategies and indicators are particularly well elaborated. Notwithstanding these findings, it can be seen that, regardless of the different levels of indicator development, there are barriers to the overall evaluation of information about CE strategies (Smol, Kulczycka, Avdiushchenko 2017) and there are no common standards for the tools and criteria defined for measurement (Haas et al. 2015).

Several indicators related to the environment and resources have been proposed by different institutions. In the case of the United Nations, the UN Environmental Program and UN Development Program have proposed indicators that include a set of key environmental indicators that contribute integrally to making progress towards the SDGs and environmental sustainability. Indicators

for sustainability reporting on corporate activities have been compiled by the Global Reporting Initiatives, covering the three pillars of sustainability (economic, environmental, and social). Another indicator (the Environmental Sustainability Index – ESI) was developed as part of a joint project between Yale and Columbia Universities and the World Economic Forum. The World Bank has compiled a set of 50 indicators to measure progress towards the Sustainable Development Goals (SDGs) and to assess important trends in environmental protection (EASAC 2016).

The vision of CE is attractive and is attracting widespread interest. *The process requires environmental indicators and targets to ensure that the economy becomes more circular and thus more integral to sustainability and sustainable development, where waste is always recycled, energy is renewable, and resources are used to create value.* Most of the indicators published about the model have been criticized for not representing the multidisciplinary nature of CE and focusing solely on measuring the extent to which material cycles are completed (Saidani et al. 2017). It is very difficult to imagine that the indicator framework can meet the definition of CE and also be consistent with sustainable development, as the concept is too narrow and lacks many important areas of interpretation (Corona et al. 2019).

Data and variables

By adopting the Circular Economy Monitoring Framework (COM(2018)29), the European Commission has created a tool for monitoring the transition, performance, trends and actions taken with regard to EU legislation (European Commission 2018). Measuring circularity is at the heart of a number of questions recently raised by researchers: i.e., how to measure the progress of the transition towards CE? (Saidani et al. 2019) Without an evaluation framework, CE initiatives cannot be sustained. *In the course of the research, the authors sought to answer the question of whether the 'measure' of the circular economy, if given by a number – in this case, a complex composite indicator – is comparable to rankings produced by other researchers.* This work was based on the Eurostat database on the circular economy for the 28 EU Member States. The research was severely limited by the fact that the indicators related to the themes are only fully available for the year 2018, so that even for the studies that provide a basis for comparison the results had to be converted to be relevant for 2018. However, the results of the research show that using a single value makes assessing and analysing the EU Member States' progress towards a circular economy much easier, although conclusions must be treated with caution, of course.

The research results contribute to the ranking of the 28 Member States of the European Union on the basis of the values thus obtained, as well as to

understanding the performance and (common or different) characteristics of each Member State in terms of the circular economy. In developing the complex indicator, the authors sought to create a methodology that facilitates the complex interpretation of the indicators collected by Eurostat for all Member States without exception. Circular economy indicators were analysed using Microsoft Excel and IBM's SPSS statistical program. The indicators are of a high measurement level, which means that they are measured on a metric scale and therefore suitable for use in the chosen statistical method. The year we addressed was 2018 and included 15 indicators representing 420 data points in total

These indicators cover four themes. *The different themes covering the circular economy contain a variable number of indicators which are generally non-repetitive, i.e., each theme occurs only once.* In some cases, the indicators also include sub-indicators, such as the recycling rate of packaging waste by type of packaging, which can be split into plastic and wood packaging. In such cases, only the indicator containing the aggregate data has been included in the analysis. In total, the authors used three indicators to cover production and consumption; six indicators to cover waste management; two indicators to cover secondary raw materials; and four indicators to cover competitiveness and innovation to create the composite indicator (Table 1).

A number of studies have addressed the criticism that it is often difficult to measure economic models and quantify progress towards objectives as the literature does not use the same sets of indicators. This database-related problem can also be identified in the present study, which is the reason that conclusions should be treated with caution when comparing them with previous research. This is due to the fact that most case studies do not use official EU statistics or simply do not examine all the 28 or 27 Member States. For rankings generated from composite indicators, a comparison can be made with the study by Garcia-Bernabeu et al. (2020) and Fura, Stec, Mis (2020). Although the latter are different in terms of the method, they arrived at similar results and conclusions as those described here by the present authors. Comparison with the work of other researchers such as Mitrović and Veselinov (2019) on composite circular economic indicators are not possible, as the latter, for example, only examined 23 EU member states.

As a critique of the indicator system, it can be said that although most definitions state that the circular economy operates using renewable energy, related indicators are not included in any of the topics, nor for the preservation of human health and similar issues. Although we compare our appraisal with the definitions of the circular economy created by numerous authors and the European Commission, it can be seen that the latter range of indicators is interpreted much more narrowly. The many areas that are mentioned may also contradict the definition of the concept, as – for example – the EU describes the CE as the use of products and services for the maximum time, which implies that

Table 1: CE-related indicators collected by Eurostat
Az Eurostat által gyűjtött körforgásos gazdasági indikátorok

Production and consumption	*Waste management*	*Secondary raw materials*	*Competitiveness and innovation*
Generation of municipal water per capita	Recycling rate of municipal water (%)	Circular materials rate	Private investment jobs and gross value added related to circular economy sectors (value added based on factor costs - EUR million)
Generation of waste excluding major mineral wastes per unit of GDP	Recycling rate of all waste excluding major mineral waste	Trade in recyclable raw materials	Private investment jobs and gross value added related to circular economy sectors (gross investment in tangible goods - EUR million)
Generation of waste excluding major mineral wastes per unit of domestic material consumption	Recycling rate of packaging waste by type of packaging		Private investment jobs and gross value added related to circular economy sectors (number of persons employed)
	Recycling rate of e-waste (%)		Patents related to recycling and secondary raw materials (number)
	Recycling of biowaste (kg/person)		

Source: authors' construction based on Eurostat[1] data collection

the range of indicators only permits a narrower interpretation. Accordingly, the EU's range of CE indicators corresponds to a concept of CE which is thus too narrowly interpreted in numerical terms. Nevertheless, the EU focuses very strongly on waste and materials in its concept of CE. This is a methodological problem, as it lacks areas that are essential in the context of today's environmental-socio-economic processes, such as the impact of climate change on the circular economy.

Methods

In the research, the authors compiled their own rankings for the 28 Member States of the European Union using composite indicators to measure progress in

the circular economy, using a scale alignment transformation. Composite indicators have appeared/are appearing in many fields and disciplines and represent an attractive opportunity to researchers as they are suitable for synthesizing a wide range of information in a unique way. Indices are used to encapsulate a multidimensional state that reduces the wide range and complexity of topics or dimensions.

Developing composite indicators can be a complex task in many respects – for example, it can be challenging to aggregate heterogeneous information (Santeramo 2016). Composite indicators can be seen as a development that can further help simplify diversified indicator systems. The primary purpose of their application is to simplify large and complex data sets. When interpreting indicators, they must be formulated very carefully, because in many cases the relationship between them is not clear. In addition, the fact that positive or negative effects in one area can be neutralized by opposite effects in other areas can also be a problem (Valkó, Kovács, Farkasné Fekete 2018).

The process of creating complex composite indicators has been conceptualised in different ways by many researchers. Nardo et al. (2005) divided the process of creating indicators into six main steps: 1) defining the phenomenon; 2) selecting variables; 3) filling in missing data; 4) homogenizing information; 5) weighting and aggregating; and, 6) validating the composite indicator. In contrast, Salvati and Carlucci (2014) established a seven-step process for the development of composite indicators, of which PCA (Principal Component Analysis) is an integral part. Compared to the five-step method presented previously, two additional steps were added to select the indicators and the best performing index.

In this paper, we describe how the authors designed a composite indicator for the circular economy of the European Union in a series of similar steps, using scale alignment transformation. Following the methodology of Nardo et al. (2005), the first three steps were carried out by the European Union on behalf of the authors. In the fourth step, the homogenisation of the data was carried out by means of a scale alignment transformation – a method that is useful when examining cases with several variables – involving combining the size and the unit of measurement of the variables, for which the following formula was used:

$$CCEI = \frac{x_i - x_{min}}{T_x} \qquad (1)$$

in which:
CCEI is the complex circular economy indicator
x_{min} is the minimum value of a given x circular economic variable
x_i is the value of the circular economic variable x
T_x is the range of the given circular economic indicator (the difference between the maximum and the minimum value) (Molnár 2018).

During the scale alignment transformation, the values of all the indicators in the dimensions will be of the same magnitude, and their values will be between 0 and 1. With this step, the degree of difference between the indicators remains the same. In the fifth step, the authors did not weight the homogenized data in the first round, but simply aggregated it, while in the last step they validated the composite indicators thus created that are associated with the Member States. However, simple aggregation may mean that the sub-sectors of the circular economy appear more pronounced when they are covered by more indicators. It is for this reason that the authors examined what happens when the indicators of the four domains of the EU circular economy model are examined domain by domain and then aggregated and averaged to determine the corresponding composite indicators and ranking.

In analysing the indicators further, the authors attempted to follow the sequence described by Nardo et al. (2005) in full, step by step, which means that they weighted (with equal weights) the indicators for the four domains before aggregating. The equal weights were necessary because it is not possible to determine which of the indicators collected by Eurostat for the circular economy have a greater role or should be emphasized. The implementation of the methodology creates a composite indicator that measures and ranks the performance of the 28 EU Member States in relation to circular economy activity. It can therefore be concluded that there is a large and freely available database about the circular economy, but any conclusions that are drawn from the analysis and evaluation of the results must be based on serious methodological and professional considerations.

Results and discussion

The aim of the study was to examine the rankings generated from the circular economy indicators collected by the European Union for its 28 Member States. In creating their own rankings, as mentioned earlier, the authors used scale alignment transformation and, in the case of composite indicators, followed the steps described by Nardo et al. (2005). In examining the 15 indicators that characterise the circular economy, as a first step the authors had to determine what impact the indicators have – i.e., whether they have a positive, neutral, or negative effect. In the research, the impact of the indicators was interpreted as negative or positive (e.g., negative for "municipal waste generation per capita" and positive for "packaging waste recycling rate by type of packaging").

Following this method, the indicators are then transformed to a value of between 0 and 1, thus preserving the differences between the original values. In a final step, the authors defined the sequence of the research. The first operation involved aggregating the normalized indicators one by one without weighting; the second summarized the indicators based on the four areas and then averaged

them. The third and final country ranking summarized and weighted the indicators based on the four areas (with simple weights) and then averaged them (Table 2). Based on their own rankings, the authors conclude that the usage of different aggregation methods results in approximately the same rank order of countries for the 28 Member States of the European Union.

Table 2: EU 28 country rankings created by the authors
A szerzők által összeállított rangsorok az EU 28 tagállamára vonatkozóan

Individual aggregation of normalised indicators without weighting[2]		*Summary and averaging of indicators according to four areas*[3]		*Summary and weighting of indicators according to four areas and averaging*[4]	
Countries	$CCEI_{2018}$	*Countries*	$CCEI_{2018}$	*Countries*	$CCEI_{2018}$
Germany	1	Germany	1	Germany	1
UK	2	UK	2	UK	2
Netherlands	3	Netherlands	3	Netherlands	3
Italy	4	Italy	4	Italy	4
France	5	France	5	France	5
Belgium	6	Belgium	6	Belgium	6
Spain	7	Spain	7	Spain	7
Denmark	8	Denmark	8	Denmark	8
Austria	9	Austria	9	Austria	9
Luxembourg	10	Luxembourg	10	Luxembourg	10
Poland	11	Poland	11	Poland	11
Ireland	12	Ireland	12	Ireland	12
Slovenia	13	Slovenia	13	Slovenia	13
Czechia	14	Czechia	14	Czechia	14
Lithuania	15	Lithuania	15	Lithuania	15
Sweden	16	Sweden	16	Sweden	16
Portugal	17	Portugal	17	Portugal	17
Finland	18	Finland	18	Finland	18

Source: Authors' construction based on Eurostat data collection

In line with the original aim of the study, the authors looked for studies against which they could compare their own research results. In support of this objective, the country rankings that were developed using the three methods were compared with those of Garcia-Bernabeu et al. (2020) and Fura, Stec, Mis (2020).

The rankings of the two studies that were examined are shown in Table 3. It can be seen that Garcia-Bernabeu et al. (2020) created three rankings depending on the perception of substitutability – i.e., the extent to which the indicators of the circular economy are perceived to be substitutable from a sustainability perspective. Fura, Stec, and Mis (2020), in a study that had a similar goal to ours, looked at the indicators of the circular economy and examined whether these

Table 3: EU 28 rankings used for comparison
Az összehasonlításhoz használt EU 28 rangsorok

Garcia-Bernabeu et al. (2020) weak sustainability[5]		*Garcia-Bernabeu et al. (2020) limited sustainability*[6]		*Garcia-Bernabeu et al. (2020) strong sustainability*[7]		*Fura, Stec, Mis (2020)*[8]	
Countries	*Ranking*	*Countries*	*Ranking*	*Countries*	*Ranking*	*Countries*	*Ranking*
Germany	1	UK	1	Germany	1	Luxembourg	1
UK	2	Germany	2	France	2	Netherlands	2
France	3	Italy	3	UK	3	Belgium	3
Netherlands	4	Belgium	4	Spain	4	Slovenia	4
Italy	5	Netherlands	5	Netherlands	5	Czechia	5
Belgium	6	Denmark	6	Italy	6	Lithuania	6
Spain	7	Lithuania	7	Austria	7	Austria	7
Austria	8	France	8	Finland	8	Denmark	8
Denmark	9	Spain	9	Denmark	9	Sweden	9
Lithuania	10	Poland	10	Luxembourg	10	Germany	10
Slovenia	11	Austria	11	Czechia	11	UK	11
Poland	12	Czechia	12	Ireland	12	Latvia	12
Czechia	13	Slovenia	13	Poland	13	Poland	13
Ireland	14	Ireland	14	Sweden	14	France	14
Luxembourg	15	Portugal	15	Cyprus	15	Finland	15
Portugal	16	Sweden	16	Belgium	16	Portugal	16
Sweden	17	Latvia	17	Malta	17	Italy	17
Finland	18	Hungary	18	Slovenia	18	Slovakia	18
Latvia	19	Luxembourg	19	Portugal	19	Ireland	19
Croatia	20	Finland	20	Greece	20	Hungary	20
Hungary	21	Cyprus	21	Croatia	21	Croatia	21
Slovakia	22	Croatia	22	Hungary	22	Spain	22
Bulgaria	23	Slovakia	23	Slovakia	23	Romania	23
Romania	24	Bulgaria	24	Latvia	24	Bulgaria	24
Cyprus	25	Greece	25	Lithuania	25	Cyprus	25
Greece	26	Romania	26	Romania	26	Malta	26
Malta	27	Estonia	27	Bulgaria	27	Estonia	27
Estonia	28	Malta	28	Estonia	28	Greece	28

Source: Authors' construction based on Garcia-Bernabeu et al. (2020) and Fura et al. (2020)

rankings could be established and how they could be used to cluster the Member States.

Our primary conclusions can also be drawn by using different aggregation methods, which show that the country rankings are roughly similar. This is also supported by a rank correlation test that was carried out, which shows that Spearman's rho is +1 in one case – i.e. the relationship between the two variables

is perfect and positive (involving the first and third rankings from the results of the authors' research's; i.e. the rankings without weighting the indicators aggregated individually, and weighting with equal weights according to the four domains, then averaged). In three cases, Spearman's rho is above 0.90, which also indicates a very strong positive relationship. For the other variants, the rank correlation values are between 0.65 and 0.81, indicating a moderately strong relationship. Of course, their significance level was also tested by the authors and found to be below 0.01 for all rank correlations, thus significant even at the level of 1%. The ranking of the 28 Member States of the European Union was established on the basis of the circular economy indicator. *Overall, this is also expressed by the country rankings of the authors and the two comparative studies, which were developed on the basis of indicators that describe the composite circular economy. The steps that have been taken towards creating a circular economy have varied widely at the EU level.*

Conclusions

The circular economy is extremely important both at the EU level and globally. Therefore, all regions must make efforts to bring it into being, as this is the only way to achieve a state of sustainable development and the circular economy approach that is an integral part of it. The long-term commitment of cities, regions, countries, and Member States is essential. The Circular Economy Action Plan package has provided exceptional assistance to Member States for implementing the transition to a circular economy. The development of economic growth and creating he elements of the circular economy are prerequisites for the harmonious development of the European Union. The circular economy will boost EU competitiveness by protecting businesses from resource scarcity and volatile prices, and by helping to create new business opportunities and innovative, more efficient ways of producing and consuming.

The transition to CE is an integral part of achieving the 2030 Agenda for Sustainable Development, especially Goals 6, 8, 11, 12, 13, 14 and 15. The drive for sustainable products is creating new opportunities for companies both inside and outside the EU. Implementing a forward-looking agenda is an essential part of achieving a more competitive and cleaner Europe. Keeping track of key trends and patterns is essential to understanding how the different elements of CE are evolving and have evolved over time. Monitoring is also needed to help identify success factors in countries and regions, and whether the necessary steps have been taken to move forward.

From an examination of the EU countries at the top of the rankings, the authors conclude that Germany, the United Kingdom, France, the Netherlands are at the top of the rankings, and Estonia and Malta are the tail-enders. On this

basis, looking at the 'performance' of Member States in terms of circular economy indicators, it can be said that Germany's first position in the rankings is due to the fact that it was the first to join in the effort to define the goal of a resource-efficient Europe within the Europe 2020 framework strategy. Many initiatives have contributed to this process, such as ProgRess I and II, which have contributed to the creation of new jobs and long-term employment (BMU 2012). At the same time, the law on the circular economy has now been adopted. A European Commission study in 2019 ranked Germany as among the best-performing Member States in terms of waste management, with a very high recycling rate (European Commission 2019b). As the authors analysed data for 2018, the role and dominance of the UK in the ranking became clear. The country published a report on resource management in 2015, and in May 2017 a specific strategic framework for a circular economy was made available for voluntary use. Real progress was made in 2018 with the introduction of the Resource and Waste Strategy (HM Government 2018).

Compared to the top two countries in the ranking, Malta is positioned bottom of the rankings. This is largely due to the country's geographical features, its strong dependence on imports, and lack of natural resources. Regardless of these factors, the small island nation has recognised the importance and relevance of a circular economy, which it sees as feasible to create through sustainable investment (Régiók Európai Bizottsága 2019). Looking at the other EU countries, Finland, the Netherlands and France have been very active in the transition to a circular economy model. Finland was the first country to introduce a roadmap towards a circular economy in 2016, implemented in cooperation with all relevant ministries, business and other key stakeholders (Berg et al. 2018). The current performance of the V4 countries in implementing the circular economy model is below that of the more advanced EU Member States, as confirmed by the rankings established by the authors and those which were used as a basis for comparison. Of the four countries, the Czech Republic and Poland typically perform "better", followed by Hungary and Slovakia. All these countries have set very high targets for sustainable development, including a circular economy.

A question that all researchers may ask is whether the circular economy can be described using a well-established indicator, as the evolution of the concept shows it to be a very complex subject. Consequently, using any method of measurement only very cautious conclusions can be drawn for each country. Obviously, the achievement of the targets that have been defined for the circular economy may be one of the benchmarks for comparing countries, as this also shows the degree of commitment to the circular economy.

However, the indicators that are available that have some connection to the circular economy also allow for its "efficiency" to be measured. The methodology makes possible the ranking of countries, making them comparable on the basis of an objective, composite indicator. The difference in ranking among countries

highlights the different levels at which countries are achieving their circular economy objectives. This may be due to the increasing emphasis on the concept of a circular economy and the fact that countries are seeking to increase their sustainability by implementing the objectives of different strategies. The next phase of the research will focus on mapping the indicators used at the company level, compiling a ranking of the circular economy from a company perspective, and comparing it with the macro ranking.

Notes

1 https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework
2 Country ranking based on the indicators for the circular economic model which involves aggregating the normalised indicators one by one without weighting.
3 Country ranking based on the indicators of the circular economy model which involves summarizing and averaging the indicators across the four areas.
4 Country ranking based on the indicators of the circular economy model which involves summarizing and weighting the indicators according to the four areas and averaging them.
5 Garcia-Bernabeu et al. (2020) - in the case of weak sustainability, the ranking allows for unlimited substitutability
6 Garcia-Bernabeu et al. (2020) - in the case of strong sustainability, the ranking does not allow for unlimited substitutability of circular economy indicators.
7 Garcia-Bernabeu et al. (2020) - in the case of limited sustainability, the ranking may have limited substitutability.
8 Fura, Stec, Mis (2020) - this synthetic measure of the circular economy was determined using a zero unitarity method.

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