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The Role of Universities in Achieving the Key Objectives of the Circular Economy Strategy

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Abstract. *The EU's Circular Economy Action Plan has guided significant changes in recent years in terms of customer behaviour, public or private models and processes. One of the biggest supports came from the education system that plays an important role in ensuring a correct and efficient application of the policy. Therefore, our study is set to fill in the gaps in the current literature by analysing the correlation between the main pillars of circular economy and higher education to determine the existence of such influence and the pattern that each EU member state follows. The results have shown full and partial validations of the considered hypotheses, with the higher education drivers having significant impact on recycling rates and waste generation, and less on the value added to the economy.*

Keywords: circular economy, higher education, university, cluster analysis

Introduction

Most writers define the circular economy as a model that closes the circle of the linear economy by using the 7Rs - recycling, reuse, recovery, refurbishment, repair, reduction and rethinking. The imperative of this new model of the economy comes after the finding of the problems we are facing at global level, and the delay of some measures applied at the level of each country, to each community implies the continuation of the destruction of the entire system of which we are all part, without bringing into question the future generations.

Using current resources so that even future generations can enjoy them is a growing challenge. For example, *overshoot day* is an indicator calculated by the Global Footprint Network that "calculates the number of days of that year that Earth's biocapacity suffices to provide for humanity's Ecological Footprint". Calculated from 1971, when overshoot day was December 25th, until 2022 it reached July 28th. Thus, at the moment, the resources produced by the planet are consumed by humanity 1.75 times faster than they are produced. According to the Journal of Petroleum Technology (2019), if every year consumption were reduced and the rate of recycling

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increased so that overshoot day delayed by 5 days annually, then we will manage by 2050 to have equality between the resources produced by the planet and the consumption.

Also, according to the Global Carbon Atlas (2021), CO_2 emissions from 2010 to 2021, at the country level, fluctuated. Thus, the USA, Japan, Germany, the UK, Italy have reduced CO_2 emissions by over 1.2 billion metric tons. In the same time, China, Indonesia, India, Iran, Vietnam increased CO_2 emissions by more than 4.4 billion metric tons. The countries with the highest values of CO_2 emissions are the USA, China, India, Russia, and Japan.

Moreover, according to a report from the World Bank (2018), it is estimated that by 2050 the annual amount of waste generated will be 3.40 billion metric tons annually. According to the same study, in 2018, each individual generates on average 0.75 kilograms of waste per day. The regions that generate a considerable amount of waste globally (43%) are East Asia and Pacific (23%) and Europe and Central Asia (20%). The most common types of waste are food and green (44%), paper and cardboard (17%) and plastic (12%). In terms of global waste treatment and disposal, only 13.5% of waste was recycled in 2018. Most OECD countries (2020) recycle a third of municipal waste (Australia, Belgium, Germany).

Only some OECD countries have improved waste management. Thus, in 2019, according to the Environment at a Glance Report (2020), they are not using the landfill method anymore (Switzerland, Germany, Finland, Sweden. Belgium). Even so, landfilling remains one of the main methods of waste disposal at the level of OECD countries.

Water pollution is another problem that the society faces. According to the Sustainable Development Goals Report (2022), over the past 300 years the Earth's wetlands have been reduced by more than 85%. Also, in 2019, more than 733 million people lived in countries with high and critical levels of water stress.

The EU's Circular Economy Action Plan (CEAP) was adopted in 2015, and the aim of it is to change the current linear model of economy to a circular one through its 54 concrete actions. A few years after its adoption, the proposed actions were carried out or implemented, according to European Commission (2019). The results of this first action plan are particularly oriented towards strategies, legislation, decisions, regulations or any other documents adopted at EU level and which can be a model for member countries. Major importance has also been attached to investment and innovation. Thus, they have secured funding through various European funds for eco-innovation projects that contribute to a circular economy.

Moreover, 14 EU member states, 8 regions and 11 cities followed the example and adopted their own circular economy strategy. Beyond the achievements of this Action Plan, the report also outlines the challenges that still require concrete and complex actions at all levels in all member states. Thus, in March 2020, the new Circular Economy Action Plan was adopted as part of the Green Deal.

The Netherlands, France, Italy, Germany, Luxembourg, Belgium, Portugal and Spain are leaders in the EU in the circular economy strategies adopted/approved together with measures, targets and achievements before 2020. At the bottom of the ranking are Cyprus, Malta, Bulgaria and Romania, which have only since 2020 or later adopted strategies. Thus, we can see a very large gap within the EU between member countries. The pace is different even though everyone recognizes the importance of the circular economy. We can also deduce a grouping of these countries according to their level of development. This phenomenon can be explained by the different focus of countries depending on the problems they face.

Thus, beyond all the steps that are taken by some countries, it is not enough at the global level. The need for involvement at the level of each country is mandatory.

Over the time it was demonstrated that education is necessary for any change. Moreover, it is the path to evolution and solves problems of any nature. Given the real problems we face, education seems to be once again one of the ways to transform the current linear economy into a circular one worldwide. We believe that the level of education influences changes, namely the circular economy, and people with higher education are oriented towards invention, recycling and investment.

This study aims to analyse the relationship between the higher level of education of EU countries and the progress of the circular economy.

It is worth mentioning that in the literature there are no studies that group countries by the degree of achievement of circular economy indicators and the level of study of the population of the respective countries. Also, the limitations of the study would be the selection of indicators.

Literature review

The study of circular economy appears to be recent in the scientific literature, similarly to sustainability or bioeconomy. The first notes on circular economy date back in the 2000s. However, authors have begun to pay more and more attention to this topic and study the relationship between the circular economy and various fields in the last 10 years. To date, 21,255 articles have been published in the Web of Science collection (Dominko et al., 2022), with the year 2022 culminating in a number of 5,563 publications (26% of all years since the first CE-related article was published). Countries with a significant contribution (39%) to the development of circular economy research are China, Italy and Spain. These being followed by England, the United States of America and Germany. Romania contributes to a very small extent (2%) – 21st place in this ranking.

The increased interest of the authors appears at the same time as the interest of public institutions manifested by the emergence of circular economy strategies, respectively action plans.

Circular economy indicators

As Garcia-Sanchez et all. (2021) mentions, monitoring the progress of the circular economy at national, regional, but especially global level is a challenge in every sense of the word.

In 2022, Matthew Fraser Head of Research and Development of Circle Economy, in the published article, states that "only 8.6% of the world economy is circular".

Currently, the indicators that monitor the progress of the circular economy at EU level are grouped into 4 categories, namely: production and consumption, waste management, secondary raw materials, competitiveness and innovation. These 4 categories comprise a total of 20 measurable indicators. For our study, 11 indicators were chosen.

According to a study (Nunes et all, 2018) in which participated the first 50 best ranked universities in the world that excel in the environment matter, it resulted that the top 5 areas on which universities are specifically focused are energy efficiency, CO_2 reduction, waste management plans, including the diversion of waste from landfill through recycling, transportation and buildings.

Thus, starting from this study that brings to the fore the contribution of universities in the circular economy, among the indicators of the circular economy of the European Union, we have chosen as relevant for our research the following indicators: Circular material use rate, Gross investment in tangible goods, Patents related to recycling and secondary raw materials, Persons employed in circular economy, Value added to circular economy at factor cost, Recycling of biowaste, Recycling rate of construction waste, Recycling rate of e-waste, Recycling of municipal waste, Recycling rate of packaging waste, Generation of municipal waste.

Indicators on higher education

Change, in general, is a lengthy process that involves several stages and resources and people. Speaking of a global change, it's even more complex. The transition from the linear model of economy to the circular one implies a change in every sense of the word. Beyond technical solutions that we can implement without much effort, except the financial one, this change involves the human resource that, most of the time, is reluctant.

According to Krebs et all (2022) the stages of change are precontemplation, contemplation, preparation, action, maintenance and recurrence. Each of the 6 stages needs time to move on to the next one. Moreover, it is well known that change begins with each of us.

Education is the basis of change, implicitly of development. According to Lange and Topel (2005) the level of education of a country (the evolution of the number of people enrolled in the educational process) influences the degree of development of that country (labor productivity and the evolution of GDP). Development itself involves change, evolution, involvement.

Moreover, Sianesi and Van Reenen (200) through their study found that a 1% increase in the enrolment rate at secondary school implies a 2.5- to 3% increase in GDP for OECD and developing countries.

The existing studies have mainly concentrated their attention on how universities can raise awareness or model people to help the transition to the new type of economy. Qu et al. (2021) have highlighted the activities that the universities can perform in support of the circular economy, grouped into four main topics: curriculum, establishing the environment, proactivity and information, dissemination and monitoring. In the same way, Sukiennik et al. (2021) presented a list of good practices towards being a responsible citizen, stating that learning should happen at all stages of education, but each with different focus points. In addition to it, Giannocarro et al. (2021) have identified the gaps in environmental education addressed to circular economy, specifically the lack of attention given to three of the existing R strategies, repair, reuse and refuse, while recycling and recovery were present in most of the related courses. Other conclusions of similar research include the necessity of adopting performance monitoring action plans at university level for all pillars of circular economy and not only research and development (Nunes et al., 2018), or planning dedicated paths for CE education such as majors or programmes (Qu et al., 2020).

The achievement of circular economy indicators and the progress of the CE is directly proportional to the current situation awareness and the importance of everyone's involvement and action. Unfortunately, awareness is not an indicator of the circular economy, nor can it be measured, which is qualitative and subjective, but it would be a very relevant indicator for all countries. Thus, the public institutions would be aware, in their turn, that there is a need to educate the population in this regard and to orient the current behaviour towards a sustainable one. Education can be the tool between the 3 important spheres of sustainability – economy, environment, social, respectively the circular economy, as long as the circular economy is part of it and cannot be treated differently.

The relationship between circular economy and tertiary education has received few to no attention from the scientific community due to their non-overlapping spheres of influence. The existing studies have determined a positive influence of tertiary education on recycling rates (Pelau and Chinie, 2018; Dumitrescu, 2020).

An impulse was given by the European Union policy makers through the Circular Economy Action Plan which set the basis for efficient quantitative analyses by developing consistent datasets and monitoring frameworks (European Commission, 2020). Therefore, four categories of

indicators have been developed and maintained to offer a view on the progress towards a circular economy and to facilitate the scientific community activity.

Consequently, our study aims to determine the patterns among the four circular economy categories of action stated by the European Commission (European Commission, 2020) based on the performance of tertiary education systems and, implicitly, the research quality in the EU states.

Methodology

The study focuses on determining similar patterns between different countries in relation to the two main concepts defined through our study: circular economy and tertiary education, testing at the same time the following hypotheses:

- H1: Tertiary education drivers influence the performance of the transition towards a circular economy.
- H2: The influence of tertiary education on circular economy, if any, appears on all levels and pillars of CE.

As a result, all 27 member states of the European Union have been selected as grouped observations to highlight the shared characteristics derived from 15 indicators presented in Table 1.

Table 1. Chosen indicators for circular economy and tertiary education

Indicator name	Unit of measure	Year	Data source
Circular economy – production and consumption			
Generation of municipal waste	Kilograms per capita	2021	Eurostat
Circular economy – waste management			
Recycling rate of municipal waste	Percentage	2021	Eurostat
Recycling rate of packaging waste	Rate	2020	Eurostat
Recovery rate of construction waste	Percentage	2020	Eurostat
Recycling rate of e-waste	Percentage	2018	Eurostat
Recycling of biowaste	Kilograms per capita	2021	Eurostat
Circular economy – secondary raw materials			
Circular material use rate	Percentage	2021	Eurostat
Circular economy – competitiveness and innovation			
Gross investment in tangible goods	Percentage of GDP	2019	Eurostat
Value added to circular economy at factor cost	Percentage of GDP	2019	Eurostat
Patents related to recycling and secondary raw materials	Number	2019	Eurostat
Persons employed in circular economy	Percentage of total employment	2019	Eurostat
Tertiary education			
Population by educational attainment level – Tertiary education	Percentage	2021	Eurostat
Lifelong learning	Score	2021	European Innovation Scoreboard
New doctorate graduates	Score	2020	European Innovation Scoreboard
International scientific co-publications	Score	2021	European Innovation Scoreboard

Source: Authors' own development

As moment in time, the latest available data has been chosen, varying within 2018 – 2021. The values were provided by two data sources, namely Eurostat for circular economy related variables and the European Innovation Scoreboard for the higher education factors.

The classification method has been applied to the existing figures to determine similarities between them and create clusters. Technically, clustering offers the possibility to find a solution to an unsupervised problem through the build of homogenous groups among the given dimension of individuals. The prerequisites of applying this type of analysis include uncorrelated variables, proven through Pearson correlation, or the existence of a clustering tendency, highlighted by a score bigger than 0.5 for Hopkins statistic. At the same time, the principal component analysis can be applied to reduce the number of variables by keeping as much as possible of the information.

The next step is represented by the partitioning, done through several methods, including K-means and hierarchical classification. The main difference between the two approaches is that the number of clusters is pre-specified in the case of K-means, while for the second method it is not known in advance (ISLR 7th print).

According to Equation 1, K-means clustering will split the observations into K clusters so that the within-cluster variation is minimised.

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \text{ (eq. 1)}$$

Where J represents the function that depends on the distance between each case x_i and centroid c_j, given the number of clusters *k* and number of cases *n*.

Stepwise, the algorithm uses the specified number of clusters to create a range between 1 and the given number and randomly assign a value from it to each observation included in the analysis. This will represent the starting point of the calculation. Further, each observation gets assigned the closest centroid based on the distance. The centroid will be updated iteratively while minimizing the variation within each formed cluster until the maximum number of iterations is reached and the clusters are stabilized.

Alternatively, the hierarchical clustering can be used to determine the subgroups, given the advantages of not pre-specifying the number of clusters and the enhanced tree-based representation through a dendrogram. As a step-by-step approach, the algorithm treats each observation as an individual cluster and pairs them based on similarity.

The best partitioning algorithm is evaluated by several statistics of which average proportion of non-overlap (APN), average distance (AD), average distance between means (ADM) and figure of merit (FOM) have been chosen due to their wide utilisation among similar analyses.

Results and discussions

Several criteria need to be confirmed as prerequisite for the core analysis. Therefore, the relationship between all combinations of the 15 indicators has been verified using the Pearson correlation.

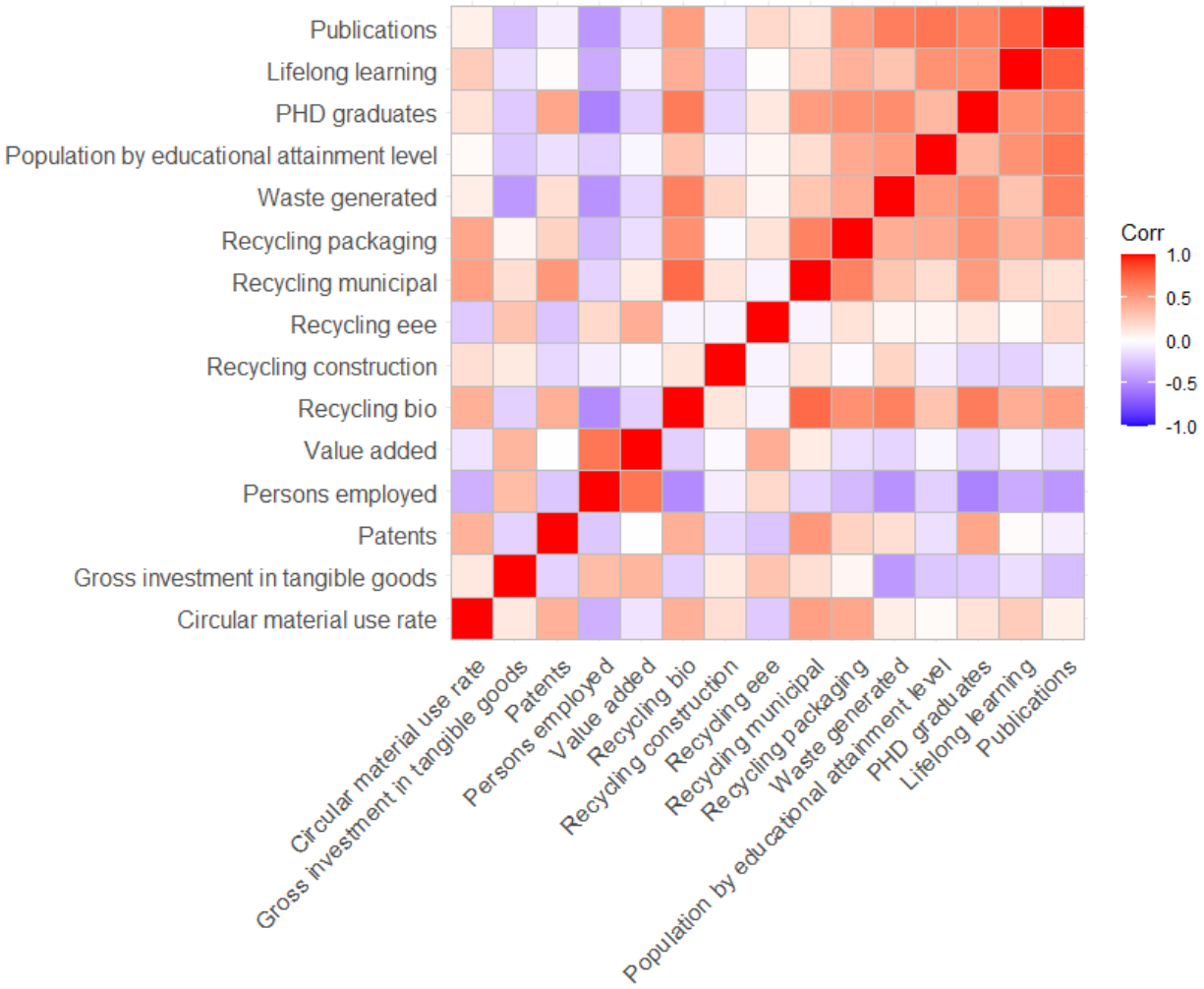


Figure 1. The correlation among each pair of indicators

Source: Authors' own development.

As shown in Figure 1, the correlation among each pair of indicators is low to medium, either direct or indirect, allowing us to state the fulfilling of the first hypothesis.

Secondly, the clustering tendency was determined using Hopkins statistic. Both the result and the visual representation have highlighted the existence of such tendency. A calculated value of 0.6 higher than the threshold of 0.5 and the presence of similarly coloured blocks of data throughout the diagonal in Figure 2 are valid confirmations that the second criterion has been achieved.

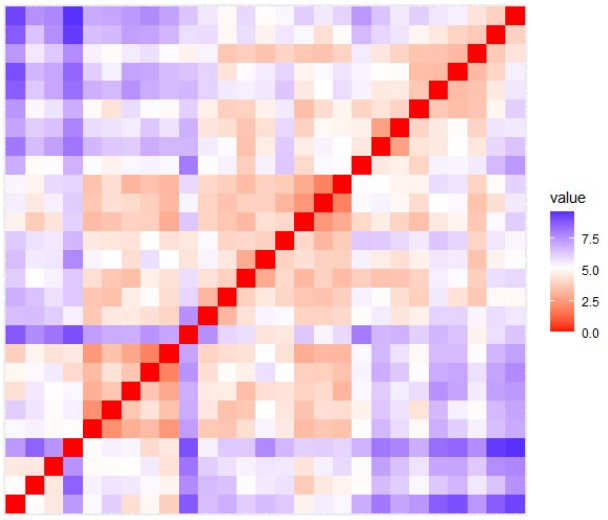


Figure 2. Clustering tendency plot

Source: Authors' own development

As the correlation between variables is relatively low, the dimension reduction through principal component analysis has not been applied, therefore keeping the entire information incapsulated by the chosen variables intact for the next steps.

The core analysis, represented by the partitioning methods, has been performed using both K-means and hierarchical classification. In the first case, Elbow and Silhouette methods were considered to determine the optimal number of clusters. As a result, the first approach recommended four groups, while the second one only two, as shown in Figures 3 and 4:

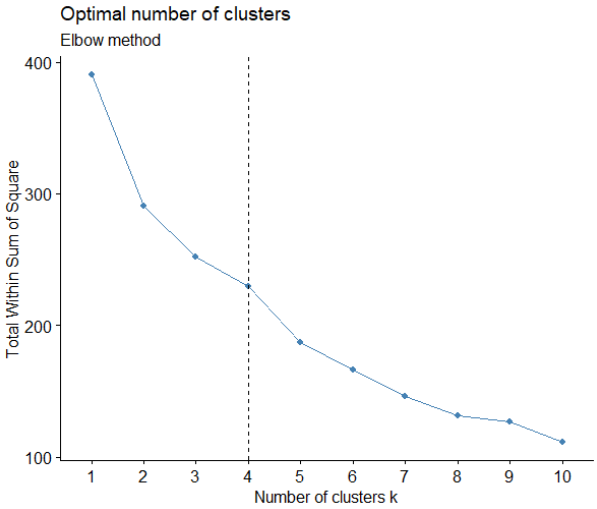


Figure 3. Optimal number of clusters k (Elbow method)

Source: Authors' own development.

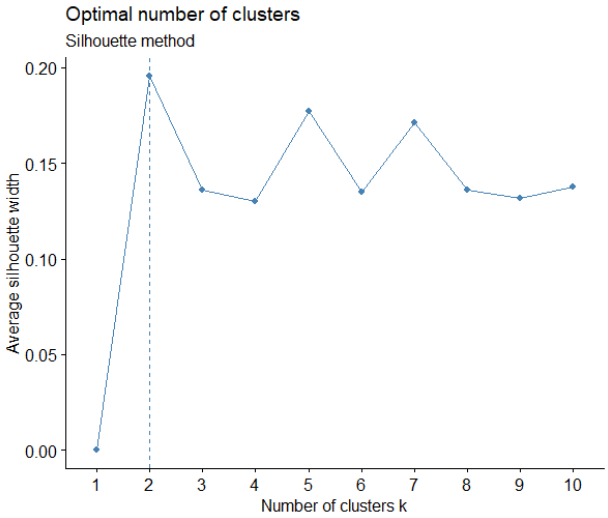


Figure 4. Optimal number of clusters k (Silhouette method)

Source: Authors' own development.

In accordance with the formulated hypotheses, we have chosen to continue with four clusters, representing:

- Cluster 1 (red): Made of states with very high levels of circular economy competitiveness, but unrelated to the quality of education or recycling rates.
- Cluster 2 (green): Represented by the countries with high performances overall, especially on waste management and efficiency of tertiary educational system, but also with high levels of generated waste.
- Cluster 3 (blue): Relatively low performing countries overall, with isolated good scores and low levels of waste generated.
- Cluster 4 (purple): Countries with very high-quality educational systems, performances in terms of recycling rates and innovation, but also with improvements required on the competitive pillar and high rates of generated waste.

The subgroups components determined by K-means are highlighted in Figure 5.

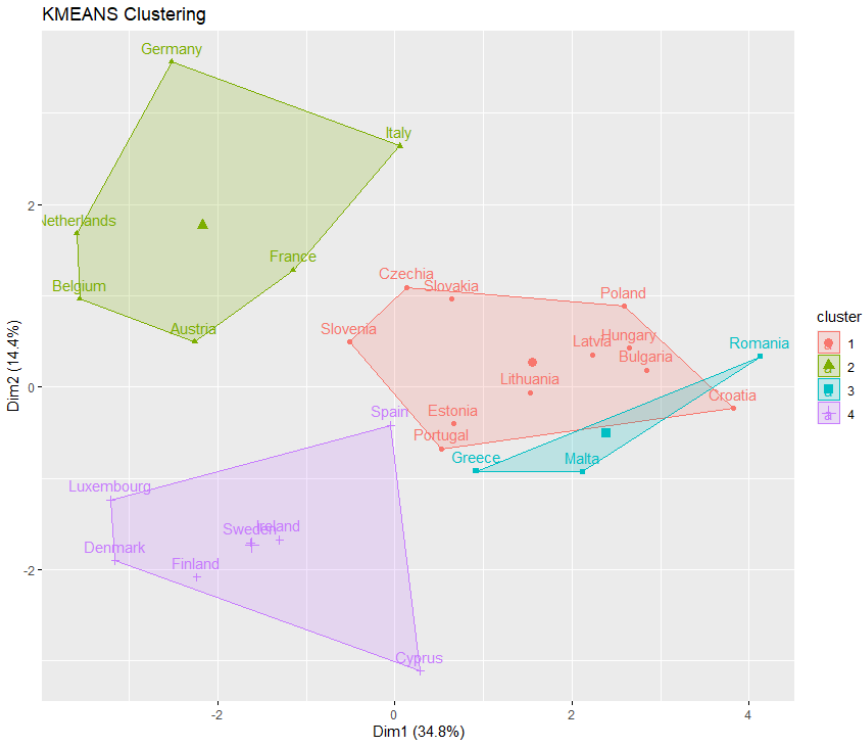


Figure 5. The subgroups components determined by K-means

Source: Authors' own development.

Most of the countries considered for the study are forming the first cluster, giving a signal to the European Union lawmakers to focus on monitoring the targets for waste management and design laws and reforms for better and competitive education systems. The second cluster is determined mainly by the economic leaders such as France, Germany and Italy that are well known for high results in research and development, as well as recycling. The third cluster, even though it has low performances in most of the variables analysed, it overlaps with the first one on many occasions, thus highlighting a potential merge soon due to the countries' determination on supporting the transition to a circular economy. Last but not least, the fourth group contains the Nordic states, recognised for their reforms in education, innovation and support for sustainable

development, and also Spain and Cyprus, with great discoveries and investments in biotechnologies and sustainable bioeconomy overall.

By running the hierarchical classification on the same data set, we have observed significant differences in the first three clusters structure, as stated in Figures 6 and 7.

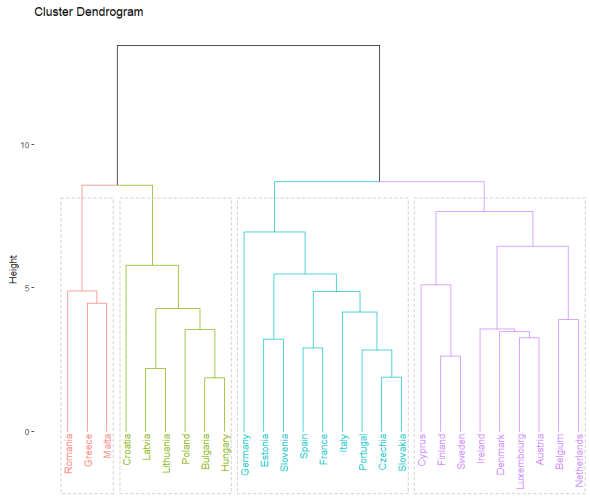


Figure 6. Cluster Dendrogram
Source: Authors' own development

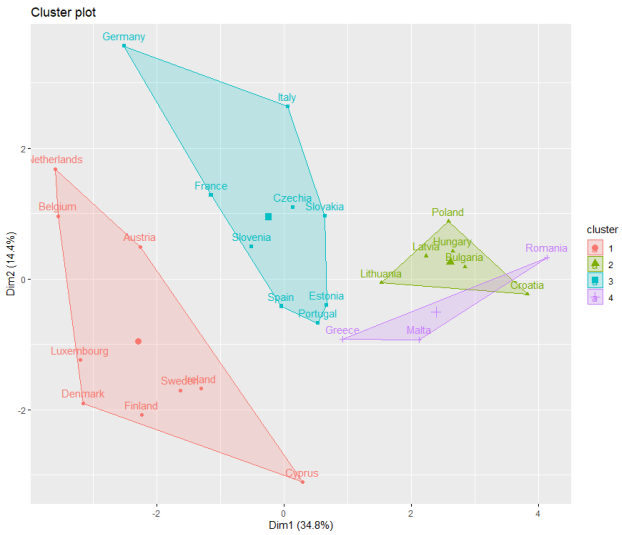


Figure 7. Cluster plot
Source: Authors' own development

The only cluster that stays unchanged is the fourth cluster, equivalent to the third one in Figure 5. At the same time, Czechia, Estonia, Portugal, Slovakia, Slovenia and Spain will form a new cluster together with France, Germany and Italy, due to their comparable progress in research and development, but also in waste management. The first cluster using hierarchical method highlights more the similarities between a high-quality tertiary education and the citizens responsibility towards a more sustainable future.

The validation step has not offered consistent results, leaving to the authors the choice of the groups structure, in accordance with the existing literature.

While APN and ADM have recommended to use the results of the hierarchical clustering, the other two tests have given opposite outcomes, represented in Table 2.

Table 2. Recommended clustering method by the type of applied test

Test	Score	Recommended method
APN	0.1782	HIERARCHICAL
AD	4.0889	KMEANS
ADM	0.8876	HIERARCHICAL
FOM	0.8881	KMEANS

Source: Authors' own development.

As a result, we have decided to validate the outcome given by the K-means clustering, due to their comparability with similar research of Nunes et al. (2018), Pelau and Chinie (2018) Dumitrescu (2020), Sukiennik et al. (2021) in terms of how the universities' approach can be applied to significantly increase the performance of circular economy drivers.

Conclusion

To date, there has been a small focus on the relationship between circular economy and education due to both weak correlation between the two concepts and the lack of quantitative resources to apply econometrical models. Thus, our study was set to fill in some of the gaps in the current scientific environment of the topic and correlate the main drivers of the tertiary education and green economy.

As a result, two main hypotheses were confirmed: H1: Tertiary education drivers influence the performance of the transition towards a circular economy and H2: The influence of tertiary education on circular economy, if any, appears on all levels and pillars of CE.

In the first case, given the existing results of Pelau and Chinie (2018), and Dumitrescu (2020), we have defined the patterns through which the universities can support a better performance towards the transition to a circular economy. Four groups of countries have resulted, with the following characteristics: states with very high levels of circular economy competitiveness, but low performances regarding the quality of education or recycling rates, countries with high performances overall, especially on waste management and efficiency of tertiary educational system, but also with high levels of generated waste, relatively low performing countries overall, with isolated good scores and low levels of waste generated, and states with very high-quality educational systems, performances in terms of recycling rates and innovation, but also with improvements required on the competitive pillar and high rates of generated waste. Therefore, Austria, Belgium, France, Germany, Italy, the Netherlands have demonstrated high results in research and development, as well as recycling, while Cyprus, Denmark, Finland, Ireland, Luxembourg, Spain and Sweden became recognized for their educational reforms, innovation and support for sustainable development. On the other hand, there are still several actions and reforms to be made by Greece, Malta and Romania on both sectors.

The second hypothesis has been validated partially through the same analysis due to the fact that the countries with significant performance on recycling have, at the same time, the best results on all the indicators related to superior education and research. The same tendency is applied to the rate of generated waste, and this can be translated into a high purchasing power that leads to consumerism. On the other hand, the value added by the circular economy is not related to a significant extent to the educational level.

The current research can be developed further by expanding the horizon on both circular economy and educational field through other factors and pillars, as well as setting a lower level of granularity by including the university level.

The limitations of the research were determined by the lack of similar studies and the small number of indicators with available data.

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