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Data mining techniques for the investigation of the circular economy and sustainability relationship

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ABSTRACT

The circular economy has gained increasing interest in academia and business due to contemporaneous policy directions. However, the metrics for measuring circular economy lack worldwide applicability. In this work, we extracted data from the LinkedIn platform regarding keywords associated with the circular economy and sustainability. The data refer to "People", "Jobs", and "Companies" for the 28 EU countries (UK included). "People" refer to relevant personal profiles, "jobs" to circular economy posted jobs, and "companies" to those companies with circular economy and sustainability activities. Using Panel time-series analysis we investigate links among the data extracted. The results show that there is a relationship among the keywords examined, indicating a strong dependence of the profiles and job posts related to sustainability with those related to circular economy. Moreover, the fixed-effects model is preferred in the 2/3 of the cases, while random-effects model in the rest of the cases. The paper proposes the LinkedIn data as an alternative proxy for the examination of Circular Economy interest, but also for other relevant fields of study. Finally, this work's merit can also be derived from the fact that our approach proves with statistical significance that the circular economy keywords affect the sustainability ones, which is in line with the current literature, that circular economy can contribute to sustainability.

1. Introduction

Circular economy is considered an important driver to achieve sustainability (Mhatre et al., 2021), as it aims to the transition of the current linear economic system to a more sustainable one (Tan and Lamers, 2021). In this context, it is not surprising that as a field, it has gained considerable attention from academia, business (Bressanelli et al., 2020), and governments (Kostakis and Tsagarakis, 2022). However, there are several implications and perspectives of the circular economy that should be analyzed in-depth (Johansson and Henriksson, 2020). There are many schools of thought that influence the way businesses and researchers approach circular economy (Salvador et al., 2021), making imperative the further examination and modeling of this topic, and the construction of models that can interpret and predict certain aspects of its parameters (Bocken et al., 2019). To do so, the need for precise, global indicators of circular economy adaptation, and worldwide metrics are necessary. Circular economy assessment and indicators are addressed by methodologies developed by international organizations and foundations, for instance, the OECD (2017), the World Bank (2017), the European Commission (2018), the WBCSD (2017), the EASAC (2016), the Ellen MacArthur Foundation (2012, 2013, 2015, 2019), and the EEA (2016).

The way countries react to the circular economy engagement, is very important, because it provides evidence for their tendency for new technology, innovation, change, and environmentally friendly practices (Knäble et al., 2022). Even though globalization has affected all countries, this effect is not the same for all, and not of the same magnitude (Kostakis and Tsagarakis, 2022). More analytically, the circular economy is a priority of the economic policy of the European Union (Smol et al., 2017), highlighting the reason why the EU provides a lot of effort (policies, funding, organizational) to transform its economy with a circular aspect (Mhatre et al., 2021; Mazur-Wierzbicka, 2021). It should not be surprising though, that the European Commission has taken several measures and has also adopted regulations implementing a new

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legal framework that allows the transition of the economy into a circular one, to strengthen the economy, increase competitiveness and ensure future sustainable economic growth (Calisto Friant et al., 2021; Mazur-Wierzbicka, 2021).

The investigation of the circular economy perspectives for the European countries is very important (Mhatre et al., 2021), demonstrated by the fact that the EU Member States have developed national indicators of circular economy (Mazur-Wierzbicka, 2021). However, national indicators of circular economy are adjusted to the adopted strategies, policies, and actions related to each country. This may be a barrier to comparing countries' performance. As stated by Mazur--Wierzbicka (2021) there is not any reference for individual countries or groups and sub-groups of countries, which poses an important question and makes apparent the need for a different approach. The monitoring framework, proposed by the literature, is not sufficient to measure all aspects that are important (Rantaa et al., 2017; Prieto-Sandoval et al., 2018).

Moreover, it is worth noting that apart from circular economy, similar difficulties in the objective monitoring and comparison of countries' performance exist regarding sustainability and the achievement of sustainable development goals (Huan et al., 2021). Sustainability is a wider notion than circularity, since the latter "focuses on resource cycles, while sustainability is more broadly related to the environment, the planet, people, and the economy" (Groene Het Brein, 2022). According to the literature, circularity attributes and practices contribute to sustainable characteristics in a global aspect (Sopjani et al., 2020), but not all sustainability attributes are known to contribute to circularity (Groene Het Brein, 2022). Furthermore, objective monitoring of circular economy and sustainability, not to mention their relationship, is considered a difficult task, due to the lack of a specific and universally acknowledged set of indicators or an indicator that could measure progress in implementing circular economy at all levels, such as sectors, enterprises, regions or states, and cities (European Environmental Agency – EEA, 2016; Elia et al., 2017; Iacovidou et al., 2017; Sánchez-Ortiz et al., 2020).

To provide a breakthrough to this difficulty, the present paper proposes an alternative and complementary approach to assess the circular economy and sustainability interest of each country, from a different view of the current literature. Our work poses a research question regarding whether LinkedIn can be used as a proxy for the investigation of the relationship between circular economy and sustainability, for the case study of the 28 European countries. The present paper derives data regarding people's and companies' profiles, and job posts related to circular economy and sustainability, from the LinkedIn platform, to examine the effect of circular economy-related keywords to the sustainability-related keywords. The data derived can be regarded to be objective, since they refer to the number of agents engaged with these notions. In this way, we can investigate whether a change in the circular economy profiles or job posts, induces a change (positive or negative) to sustainability ones. The dependent and independent variables selection is based upon the works of Mesa et al. (2018), Padilla-Rivera et al. (2021), and Dantas et al. (2021), since these authors have already proven that circular economy (being a more specific term) drives sustainability (being a more general term). In this way, instead of measuring the performance of the various agents related to these notions, to investigate this relationship, we examine the LinkedIn "factors" that relate to these notions, examining their relationship.

This paper fills a gap in the literature, by being the first to propose and utilize readily available information linking circular economy with sustainability, suggesting a new macro metric, collected with the same approach under the different regions. Furthermore, our work contributes to the literature by using hits of specific keywords in the LinkedIn platform, regarding circular economy, and sustainability, suitable for panel time-series analysis. Finally, this paper is the first to carry out such a study for 28 European countries, examining their performance in this specific field of study, proving in this way the comparability of the metrics formulated, and their universal applicability.

Following this introduction, the paper is structured as follows: Section 2 presents the review of the literature; Section 3 describes the methodology used, Section 4 presents the empirical results, followed by their discussion in Section 5, and finally, Section 6 concludes the paper.

2. Literature review

This section presents the state of the art on the relationship between circular economy and sustainability, followed by some metrics and social media relevance.

2.1. Circular economy, sustainability, and their relationship

Worldwide consumption has increased many times over the decades, and it is expected that resource use will increase even more (Lucas et al., 2014). The effect of population growth and the increase in consumption poses some important questions about the capacity of the environment, concerning the depletion of global resources (Upadhyay et al., 2021). The Circular Economy has gained attention from academia and industry, as it is considered a potential way to effectively manage the available and scarce resources (Velenturf and Purnell, 2021). This renders the circular economy an emerging and crucial field of study (Nikolaou and Tsagarakis, 2021).

There are many interactions of circular economy with other environmental protection concepts, such as sustainable development (Millar et al., 2019), climate change mitigation (Chizaryfard et al., 2020), green growth, zero waste, and minimization of environmental impact (Zink and Geyer, 2017; Korhonen et al., 2018). The circular economy may primarily affect infrastructures (Kucukvar et al., 2021; Ki et al., 2021a), industries (Koop et al., 2021) mining (Smol et al., 2020; Upadhyay et al. 2021), recycling (Ki et al., 2021b) and renewable energy (Farooq et al., 2021), but also the whole organization of the society so interventions and new ways of thinking (Skene, 2022) are necessary. On the other hand, some researchers argue that apart from a general decreasing trend in production and consumption in a circular economy, there are cases that a possible increase in production and consumption, could take place. This condition is termed as circular economy rebound (Zink and Geyer, 2017; Makov and Font Vivanco, 2018). All the aforementioned render the quantitative and qualitative analysis imperative. To begin with, Bolger and Doyon (2019) and Gravagnuolo et al. (2019) argue that there are multiple ways, in which local governments and cities act as change agents in their interaction, with external stakeholders also, to support the transition to a circular economy. In a similar manner, Keramitsoglou et al. (2023) describe how students' awareness on circular economy can be increased by active participation to virtual enterprises.

Furthermore, we should point out studies that have tried to unveil a connection between circular economy, sustainability, and other notions related to circularity. For instance, Arruda et al. (2021) examined the different perspectives and concepts of circular economy, through a bibliographical approach, and argue that the way the evolution of circular economy will take place, is not profound, highlighting the necessity of further research on this specific subject.

According to Christensen Budde (2021) circular economy policies and sustainable city planning, are important issues for society. The author argues that municipalities can perform as an important change agent to support a transformation toward a circular economy. van der Velden (2021) has pointed out the importance of the circular economy, and more precisely the community repair to society. The author states its importance, as it may be considered a sustainable way of living with things in a circular economy. Moreover, Grafström and Aasma (2021) examine the technological, market, institutional, and cultural barriers to the circular economy. The authors argue that even small barriers can stop the emergence of a circular economy. Moreover, Barros et al. (2021) examine the implications of circular economy on business areas. Based on the authors, there exists an effect of the circular economy on business areas, stating also that adopting a circular economy may render more sustainable organization.

2.2. Metrics of circular economy and sustainability

Circular economy and sustainability are important notions, and thus, it should not be surprising that several studies have tried to quantify many countries' performance regarding these notions, and also these notions' relationship. Among those studies are the works of Vadoudi et al. (2022) and Jiang et al. (2022) focus on a product level approach, while Siddique et al. (2022) on industry, and Lee et al. (2021) and Giannoccaro et al. (2021) on a regional level. Gupta et al. (2019) examine the circular economy, using a data analytics approach. More precisely, the authors utilize big data analytics as a basis for informed and data-driven decision-making in supply chain networks supporting the circular economy and propose a model to achieve shared sustainability goals.

Additionally, circular economy, sustainability, and sustainable development goals are closely related (Velenturf and Purnell, 2021; Belmonte-Ureña et al., 2021), since CE can contribute to sustainable performance (Mesa et al. 2018) and help to achieve several SDGs targets (Padilla-Rivera et al., 2021). However, this relationship is not always profound and is even more difficult to measure. Martinho (2021) argues that circularity involves different dimensions and can be accessed through several indicators. In cases of interrelationship analysis, between the circular economy and sustainability, these indicators are even scarcer. The author performed meta-data assessment and bibliometric analysis showing that it is important to find more and more recent sustainability indicators concerning the circular economy since those that have already been chosen by scientific literature fail to address relevant dimensions.

Dantas et al. (2021) argue that CE is linked with the achievement of the SDG targets since it connects innovative technologies with novel circular production techniques and business models, a combination that renders the SDG targets more feasible. Based on the authors' further quantitative research can investigate such a connection.

Lange et al. (2021) state the importance of circular business models, performing an analysis using agent-based modeling and simulation, proposing improvement over the circular business models design, from the company to the network level. Similarly, Calzolari et al. (2021) studied the circular economy-inspired initiatives promoted by the largest European Multi-National Enterprises (MNEs). The authors provide results for the sustainability reports, through template analysis technique, creating a database of circular economy practices. Their findings include the level of involvement of supply chain partners, the degree of implementation, and the drivers behind the implementation of these practices. The authors highlight the role of supply chain integration and institutional pressures in the transition toward the adoption of circular economy practices in global supply chains.

As for the case of European countries, D'Adamo and Rosa (2016) analyzed the assessment of the European renewable energy source (RES) trajectory towards 2020, proposing a reference framework, to evaluate RESs performances in Europe. The authors argue that twenty-seven countries reached their 2013/2014 intermediate renewable energy targets, implying a significant performance. According to the authors, their method does not include dynamic features.

Cucchiell et al. (2017) examined the sustainability performances of European countries from the environmental and energetic perspectives, proposing a Multi-Criteria Decision Analysis with multiple indexes. Based on the authors' results, twelve out of twenty-eight European countries have a value greater than the European average in 2013. Tantau et al. (2018) using the panel regression technique, examined the dependency between main indicators that indicate the progress of the circular economy in Europe (for example the recycling rate of municipal waste, R&D expenditure by sectors, circular material use rate, resource productivity, trade-in recyclable raw materials and environmental tax revenues, domestic material consumption). The authors argue that there is a relationship among the indices examined, for the European countries, with the random effects model being better than the fixed effects model, indicating that the country-specific effects do exist, but they are not correlated with the coefficients on the other variables.

Moreover, Obersteg et al. (2019) analyzed circular economy initiatives in European urban areas, unveiling a general lack of public sector support for private initiatives. Furthermore, Robaina et al. (2020) investigated the efficiency of resources' productivity, as an indicator, to compare how circular economies perform in Europe, using clustering and panel data techniques. Based on the results, European countries seem to cluster into three groups (based on the growth rate of the productivity of their resources). D'Adamo et al. (2020) proposed a new indicator, namely the "socioeconomic indicator for the bioeconomy" to measure the social and economic performance of bioeconomy sectors for the European countries. The results identify three groups of member state performance (virtuous, in-between, and laggard) concerning the European average. More analytically, Ireland occupies the first position in the ranking, and only three other member states (Denmark, Portugal, and Austria) can be characterized as "virtuous" countries.

Finally, according to De Pascale et al. (2021), 61 indicators try to measure CE, based on a literature review of 137 articles, but even though there are many levels of indicators that try to measure the CE, however, analytical, precise, and up-to-date measurements and documentations of the progress towards CE do not exist (Kristensen and Mosgaard, 2020). Objective metrics and indices are very important because they provide comparable results (Marti and Puertas, 2020; Arbolino et al., 2022) also capable of providing insights regarding the relationship between sustainability and circular economy. However, current existing indicators are not sufficient regarding their robustness, to assess the sustainability performance of circular systems (de Oliveira et al., 2021). Apart from that, there are no adequate methods regarding the quantitative assessment of the progress of achieving sustainability dimensions (Huan et al., 2021), and thus, the analysis and quantification of the SDGs' degree of achievement are very difficult. In this context, the tracking of countries' progress over time toward the SDGs can be misleading (Hametner and Kostetckaia, 2020) and according to Swain and Ranganathan (2021) a universal benchmarking of SDGs with high precision may be even impossible. In this context, although many breakthroughs have taken place for the introduction and use of objective metrics and indices, many of them are insufficient.

2.3. LinkedIn and social networks as a source of information

Data from social networks have been used on many occasions to provide useful results. For example, Saura et al. (2022) use Twitter as a source of information regarding the boundaries and contribution of open innovation. Similarly, Orcan et al. (2021) use the same data source to explore trends regarding sustainability, technology and product development. In the same context, De Lima (2022) used Twitter to analyze the way CE is conceived and implemented by practitioners, sharing their viewpoint about this important notion, commenting on the probable practices, drivers, and results.

As for LinkedIn, it has already been used for the examination of job characteristics, but in other fields of study. For example, Davis et al. (2020) using a mixed-mode survey, collected data from professionals, and also data from the LinkedIn platform analyzing job characteristics and career benefits. The authors argue that the number of contacts was not an important factor, but the frequency of usage mattered for the career benefits. Repp et al. (2021) studied quantitatively the employment effects of the EU transition on a global scale, including also a discussion about the ethical dimensions. The authors argue that employment can decrease in low and upper-middle-income countries outside the EU, and on the other hand, can increase in less labor-intense downstream reuse and recycling activities in the EU. Also, second-hand retail can increase in general.

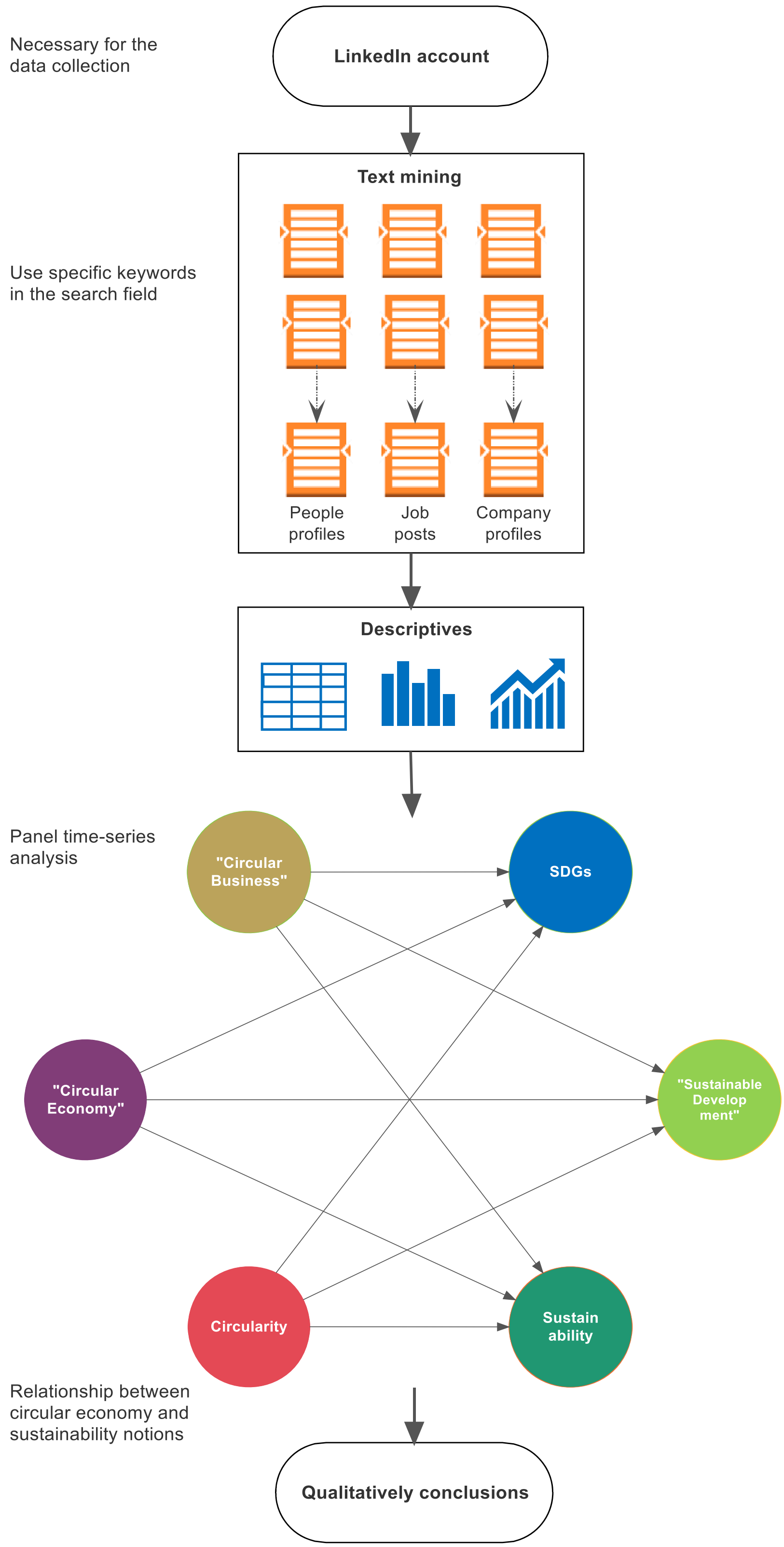

Fig. 1. Research methodology plan.

Furthermore, Baruffaldi et al. (2017) investigated the determinants that drive the Ph.D. graduates to create a LinkedIn profile, and developing networks, in this way. Kaliszewski et al. (2021) used LinkedIn as a proxy for collecting data from a survey to perform an analysis regarding the competitive factors of container terminals. Similarly, Kozłowski et al. (2021) also propose LinkedIn as a source of information, capable of performing surveys. Ecleo and Galido used LinkedIn as a source of data to perform an analysis regarding the features and skills of data scientists. Furthermore, Fernandez et al. (2021) employed LinkedIn data to investigate the accuracy of personality traits' identification. Moreover, according to Lopez-Carril (2020), LinkedIn can be used in sports management and education, while Kauffman et al. (2022) argue that it can be used for educational purposes, also proposing methods to merit from its strengths and avoid certain difficulties that may be present. Finally, Tsironis et al. (2022) use the LinkedIn platform to summarize and present the companies that engage in circular economy, also performing statistical analysis regarding the distribution of the companies, proposing in this way a metric of the countries' engagement in CE practices. An extension of this methodology has been used by Knäble and Tsagarakis (2023) to look for the circular economy evolution in companies for German federal regions.

Summing up, based on the previous works, the literature lacks a widely applicable metric for the CE and sustainability investigation, also capturing the relationship between them using econometric analysis. To fill this gap in the literature, our work poses a research question regarding whether LinkedIn can be used as a proxy for the investigation of the relationship between circular economy and sustainability, for the case study of the 28 European countries, taking into account People's profiles, job posts, and companies, providing in this way objective complementary metrics in the form of a possible variable or index, if periodically extracted.

3. Methodology

In this section, we present the data and the variables used in the present work, derived by the LinkedIn platform, and we then set out the panel models we implemented, describing also how we planned the exploratory analysis. Fig. 1 provides an overview of the steps followed. After the periodic data mining and treatment, we provide some descriptive illustrations per country. Then, we perform a statistical exploratory analysis.

3.1. Data and variables

In this work, we derived data from the LinkedIn platform referring to People, Jobs, and Companies for the 27 EU countries and UK, since this country has been a pioneer in promoting the emergence of circular practices in the business sector, through innovation.. The data refer to six keywords associated with the circular economy and sustainability. More precisely, these keywords are "Circular Economy", "Circular Business", Circularity, SDGs, Sustainability, and "Sustainable Development". The quotes declare in the search that the words must be in a specific order, while without quotes, the search takes into consideration simply the existence of these words (in general), and not, necessarily, in a specific order. In this way, SDGs, Sustainability, and "Sustainable Development" are the dependent variables, while "Circular Economy", "Circular Business", and Circularity are the independent variables, forming three panel structures, People, Jobs, and Companies for 28 EU countries, with four extracts from May of 2021 till June of 2021, with biweekly data extraction. The data extraction was based upon the English language (see also Tsironis et al., 2022), to render our sample homogenous, since national terms indicate zero or significantly lower results than the English corresponding terms searched, with the only exception of Sweden, which can be regarded as an outlier. Regarding the data, "people" refer to personal profiles, "Jobs" to related job posts, and "Companies" to those companies with circular economy or sustainability activities, selected based on the six keywords mentioned above. The data extraction requires a LinkedIn account and was repeated for each of the EU-28 countries that were selected for this work for each of the sampling period. After testing relevant keywords and quotations related to the notions of circular economy and sustainability, respectively, we concluded to these six keywords, due to data availability, i.e. hits in most countries, data smoothness and variability. Thus, the outputs have been profiles and posts with the search term included in any section of their text-body, implying a significant relevance with the examined topic. Furthermore, it should be clarified that we do not check the actual validity of profiles' statements since we follow a research logic similar to a survey analysis with data that could be alternatively obtained through questionnaires with similar reliability level regarding the quality. As a next step, using Panel time series analysis, we investigate a probable link among the data for the keywords extracted. The analysis was implemented using the R programming language and Rstudio.

3.2. Model structure

As a first step, we process the data derived by the LinkedIn platform that were obtained in raw format. We then formulate the three datasets (People, Jobs, and Companies) in panel-like dataset formats, structuring the panel models, based on the countries and the dates (as indices for the panel specification).

The next step, as in every econometric time-series approach, includes a unit root test. More precisely, we implemented the Maddala and Wu unit root test (Maddala and Wu, 1999). In this context, if a unit root exists, then first differences will be introduced, while if there is no unit root, we may proceed with levels. The null hypothesis of the test is that it contains a unit root, and therefore it may be considered non-stationary, while the alternative hypothesis is that it does not contain a unit root, and therefore it may be considered stationary.

We then test whether a fixed-effects or a random-effects model is appropriate for our case, performing the Durbin–Wu–Hausman test also called as Hausman specification test (Durbin, 1954; Wu, 1973; Hausman, 1978; Nakamura and Nakamura, 1981). The null hypothesis of the test is that the random effects model is better (due to higher efficiency) while the alternative hypothesis is that the fixed effects model is better (at least as consistent).

3.3. Exploratory analysis

Based on the literature, circularity characteristics tend to contribute to sustainable characteristics in the global economy (Sopjani et al., 2020), but not all sustainability attributes contribute to circularity (Groene Het Brein, 2022). According to many researchers, circular economy is a substantial condition to lead to sustainable goals (UNEP, 2006; Läpple, 2007; Rashid et al., 2013; Bakker et al., 2014), while for others, it is regarded as a necessary characteristic but not sufficient (Nakajima, 2000). Sustainability as a term is more general and includes many characteristics that are absent in circular economy, for instance, circular economy lacks an elaborated description of the social dimension that exists in sustainability, with its principles being based upon a business perspective striving also for environmental and economic benefits (Mantalovas and Di Mino, 2020). Knäble et al. (2022) analyze the impact of the four Circular Economy value sources Renewable Energies, Repairing/Remanufacturing, Reuse/Sharing, and Recycling on the three dimensions of Sustainable Development: i. social (unemployment rate), ii. environment (GHG emissions), iii. economic (GDP).

In this point of reference, following the literature, we examine whether circular economy-related LinkedIn data affect sustainability-related LinkedIn data, through panel regression modeling. In this context, each equation describes the respective dependent variable (sustainability-related keyword) as a linear function of the independent variables (CE-related keywords). We then capture the coefficients of the models, and we test the statistical significance of the variables, concluding whether the effect of the circular economy on the sustainability-related LinkedIn data is statistically significant. This can be regarded as a novel approach in this specific field of study, especially for such examinations.

So, we set three panel models, one for the case of People, one for the case of Jobs, and one for the case of Companies accordingly. The structure of the models for each case (People, Jobs, and Companies) is the following:

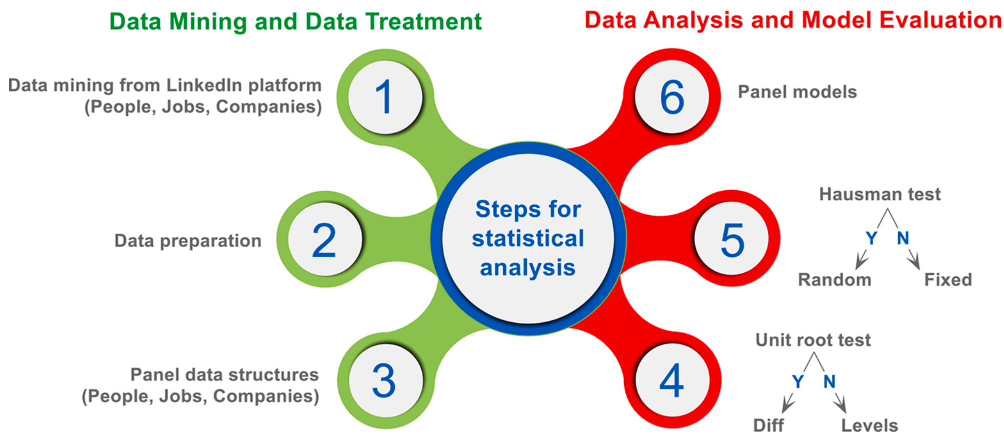

Fig. 2. Statistical analysis methodology plan.

$$SDGs = \begin{cases} a_0 + a_1 * \text{CB} + a_2 * \text{CE} + a_3 * \text{Cir}, & \text{if random} - \text{effects is preferred} \\ a_1 * \text{CB} + a_2 * \text{CE} + a_3 * \text{Cir}, & \text{if fixed} - \text{effects is preferred} \end{cases}$$

$$Sustainabily = \begin{cases} b_0 + b_1 * \text{CB} + b_2 * \text{CE} + b_3 * \text{Cir}, & \text{if random} - \text{effects is preferred} \\ b_1 * \text{CB} + b_2 * \text{CE} + b_3 * \text{Cir}, & \text{if fixed} - \text{effects is preferred} \end{cases}$$

$$\begin{matrix} \text{"Sustainable} \\ \text{Development"} \end{matrix} = \begin{cases} c_0 + c_1 * \text{CB} + c_2 * \text{CE} + c_3 * \text{Cir}, & \text{if random} - \text{effects is preferred} \\ c_1 * \text{CB} + c_2 * \text{CE} + c_3 * \text{Cir}, & \text{if fixed} - \text{effects is preferred} \end{cases}$$

Where

CB: "Circular Business"
CE: "Circular Economy"
Cir: Circularity

As regards the physical meaning of the models, since data refer to the number of agents engaged with these notions, by capturing these models, we investigate whether a change in the circular economy profiles of job posts, induces a change to sustainability ones. This proves the presence of a relationship between circular economy and sustainability using social media data (i.e., LinkedIn). The statistical analysis methodology is summarized in the flowchart of Fig. 2.

4. Empirical analysis

This section provides a descriptive presentation of the collected data, followed by the statistical panel data analysis.

4.1. Descriptive analysis

At first, we present normalized data graphs regarding the average hits for selected keywords during the study period. These graphs (Fig. 3) show the distribution of the keywords for the countries examined, which is quite essential for the topic we examine given the relatively short time span of our data. There has been a normalization per half-million population, so there are meaningful comparisons even for the smaller EU countries. For "Circular Business" in companies' profiles, first comes Luxembourg, followed by the Netherlands and Denmark (Fig. 3a). Regarding the companies with "Circular Economy" in their profile's description, Luxembourg comes first, followed by Slovakia and the Netherlands (Fig. 3b). Luxembourg is also the first country in "Circularity" related companies, followed by Denmark, Ireland, and the Netherlands, with almost every other country being placed near zero value (Fig. 3c). Further descriptive statistics of keywords per country are presented in the supplementary file.

The circular economy-related keywords in English term are dominant in the profiles compared to the translated equivalent term in the national language, except for Sweden. So, comparisons of Graphs in Fig. 3 are meaningful. The relatively short time span of the data, especially in cases where the keyword hits were few in number (eg. Job posts), and in combination with the small population for specific countries, can further contribute in the intensity of the impact of certain changes on the results, during the examined period, which would not be the case for longer periods. This means that such changes can affect the results, rendering imperative a more thorough analysis with more data available, for a greater period.

4.2. Panel data analysis

The statistical analysis starts with the investigation of the stationary characteristics of the panel data, performing a unit root test. Then, we examine whether a fixed-effects model is preferred over a random-effects model, and we finally set panel regression models based on the Hausman test, capturing the coefficients and the summary statistics of the models. We first present the Unit root test results (Table 1).

The results show that the three panel data structures (People, Jobs, Companies) are stationary, so, we may proceed with our analysis in

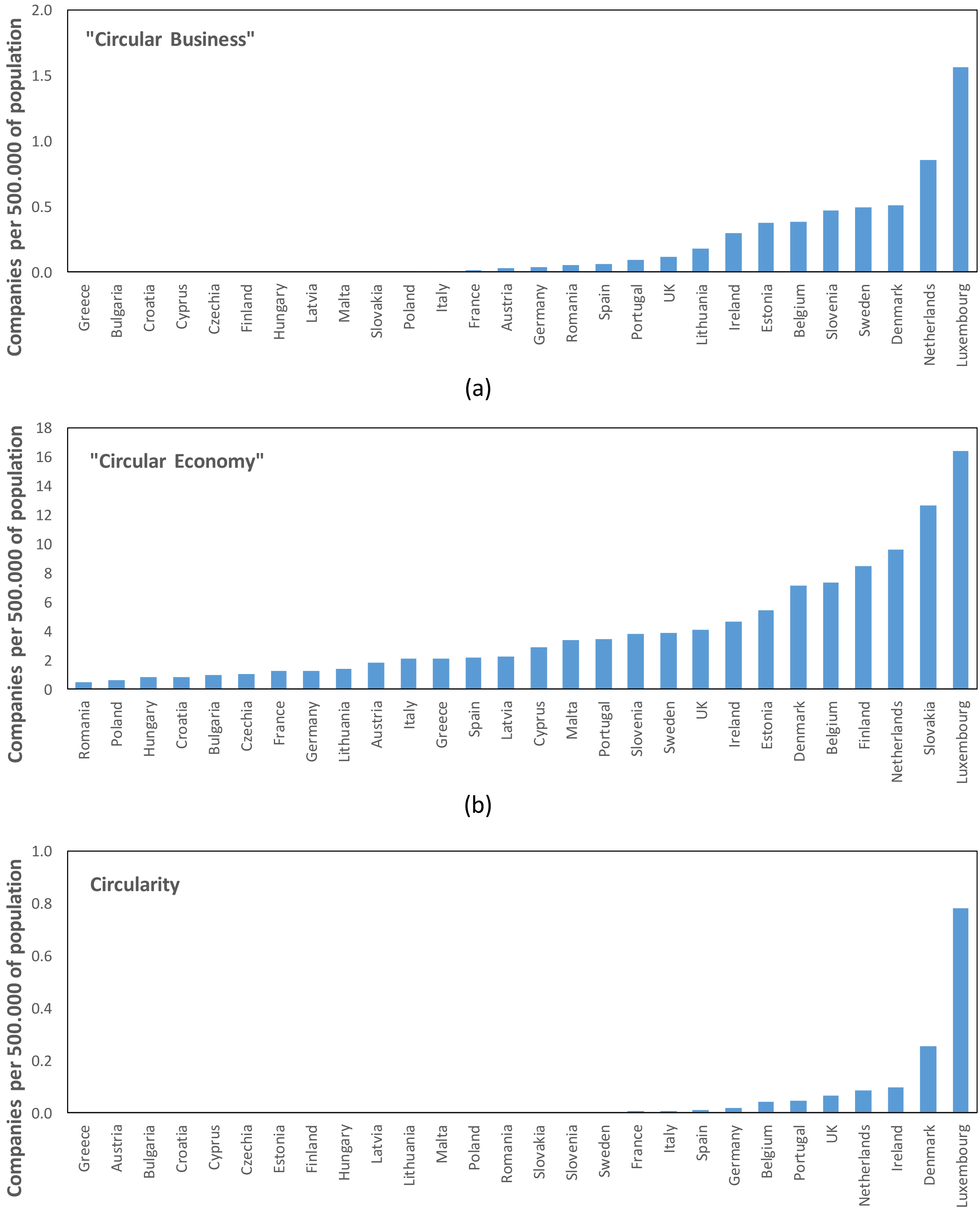

Fig. 3. Distribution of LinkedIn company ("Companies") profiles per country, normalized based on the population during the study period, for circular economy related keywords: a. "Circular business", b. "Circular economy", and c. Circularity.

levels. As a next step, we perform the Hausman test to decide whether a fixed-effects model is better than a random-effects model.

The findings presented in Table 2 indicate that for all cases (People, Jobs, Companies), for two equations the fixed-effects model is preferable and for one the random-effects model. This means that 2/3 of the cases should include a fixed-effects model, while the rest of the cases, a random-effects model. We then implement these models, based on the Hausman tests, capturing the coefficients and the summary statistics of the models, depicted in Tables A1, A2, A3 of the Appendix.

For the case of People (Table A1), in the first model, the keywords "Circular Economy" and Circularity are positively related to the SDGs keyword with statistical significance. In the second model, only the

Table 1
Maddala and Wu unit root test for the three panel structures.

Panel model	Maddala and Wu unit root test	*p*-value	Stationary
People	47.527	<0.001	YES
Jobs	132.97	<0.001	YES
Companies	34.871	<0.001	YES

keyword "Circular Economy" is statistically significant and is positively related to the Sustainability keyword. Finally, in the third model, only the keyword "Circular Economy" is statistically significant and affects the keyword "Sustainable Development" positively.

For the case of Jobs (Table A2), in the first model, the keywords "Circular Business" and Circularity affect the SDGs keyword with statistical significance. More precisely, "Circular Business" affects the SDGs keyword negatively, while Circularity positively. In the second model, the keywords “Circular Economy” and Circularity are statistically significant and affect the Sustainability keyword positively. Finally, in the third model, all three keywords, namely, "Circular Business", "Circular Economy" and Circularity are statistically significant and affect the keyword "Sustainable Development" positively.

For the case of Companies (Table A3), in the first model, the keywords "Circular Economy" and Circularity affect positively the SDGs keyword with statistical significance. In the second model, the keyword Circularity is statistically significant and affects the Sustainability keyword positively. Finally, in the third model, the keywords "Circular Economy" and Circularity, and also the intercept are statistically significant and affect the keyword "Sustainable Development" positively.

The estimates presented in Tables A1, A2, A3 and illustrated in Fig. 4 indicate a strong relationship between the independent variables and the dependent with all the statistically significant variables affecting positively the dependent variables, except for the “Circular Business” in the SDGs model for the case of Jobs. This means that an increase in all circular economy-related keywords (except for the “Circular Business” in the SDGs model for the case of Jobs) leads to an increase in the sustainable-related keywords.

5. Discussion

In this work, we derive data from the LinkedIn platform, examining Circular Economy and sustainability characteristics for 28 European countries, referring to People, Jobs, and Companies. The data shows that the circular economy and sustainability gain momentum in the global environment, validating the EU policies for circular economy and sustainability.

5.1. Interpretation of the results and contributions

The results show that fixed-effects models are preferred over the random-effects models for 2/3 of the cases. More analytically, regarding these models, for the case of People, the keywords "Circular Economy" and Circularity affect the SDGs keyword, while the keyword "Circular Economy" affects the Sustainability keyword, respectively. Similarly, for the case of Jobs, the keywords “Circular Economy” and Circularity affect the Sustainability keyword, while "Circular Business", "Circular Economy" and Circularity affect the keyword "Sustainable Development". Finally, for the case of Companies the keywords "Circular Economy" and Circularity affect the SDGs keyword, and the keyword Circularity affects the Sustainability keyword. These results are statistically significant based on the *p*-values. These relationships are all positive, which means that an increase in any of the circular economy-related keywords, leads to an increase in the sustainable-related keywords. For these models, the country-specific effects do exist and are correlated with the coefficients on the other variables. Hence, the countries examined differ in this behavior, but a relation exists.

On the other hand, for the other 1/3 of the cases, the random-effects model is preferred. Based on the findings, for the case of People the keyword "Circular Economy" affects the keyword "Sustainable Development", for the case of Jobs the keywords "Circular Business" and Circularity affect the SDGs keyword, while for the case of Companies the keywords "Circular Economy" and Circularity, and also the intercept affect the keyword "Sustainable Development". These results are statistically significant based on the *p*-values. The aforementioned effects are positive (except for the model of SDGs for the case of Jobs), which means that an increase in all circular economy-related keywords, leads to an increase in the sustainable-related keywords. As for the exception, the model of SDGs for the case of Jobs, the keyword Circularity affects the SDGs positively, while the "Circular Business" keyword negatively. This unexpected negative effect, of the keyword "Circular Business" in the SDGs keyword, may be attributed to data availability, since there are many zeros in this variable, necessitating the need for more thorough research if more data become available. For the aforementioned models, the country-specific effects do exist but are uncorrelated with the coefficients on the other variables.

The present paper proposes a different and unique approach in this specific field of study, through LinkedIn data analysis. In this way, this work contributes to the literature, since, as stated by many researchers (see among others Martinho, 2021; D’Adamo and Rosa, 2016; and D’Adamo et al., 2020), the data and the approach to the investigation of Circularity and Sustainability perspectives, especially of global aspect, is not profound and also not fully-stated. Finally, our results are following the literature, since we find that there is a connection between concepts regarding the circular economy and sustainable development (Velenturf and Purnell; 2021). In the same context, we prove that LinkedIn can be used to derive information regarding countries’ engagement in CE and sustainability, and their relationship, as well, which is also in line with the work of Tsironis et al. (2022) which also proves the LinkedIn platform’s contribution to such investigations.

Our work, through a combination of quantitative and qualitative features, by providing results in line with the literature, proves that our novel proposed approach can provide important insights with objective characteristics regarding the relationship between CE and sustainability. This renders our approach unique.

Table 2
Hausman test result for the panel model of people, jobs, and companies.

Dependent variable	People Hausman test	*p*-value	Jobs Hausman test	*p*-value	Companies Hausman test	*p*-value
SDGs	34.838	<0.001	4.343	0.227	28.356	<0.001
Sustainability	17.446	<0.001	58.757	<0.001	32.368	<0.001
"Sustainable Development"	3.678	0.298	10.143	0.017	1.974	0.578

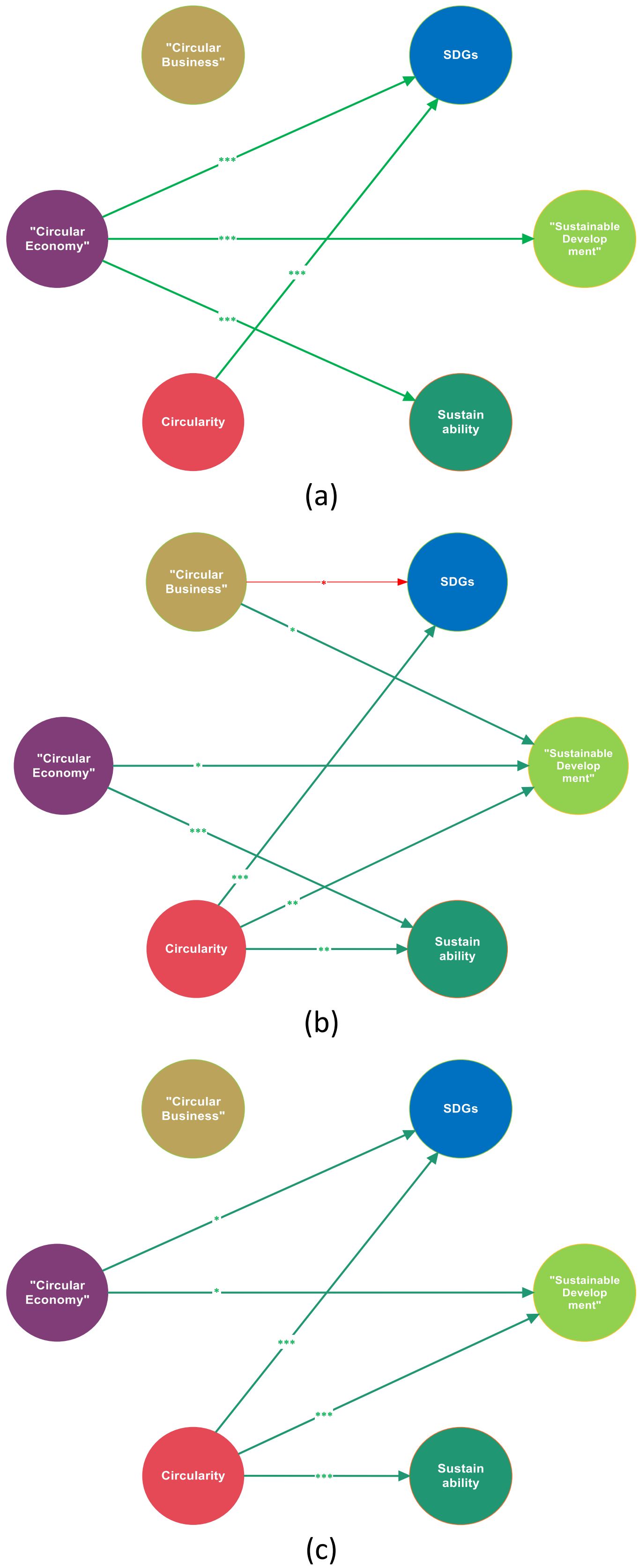

Fig. 4. Statistically significant variables explaining SDGs, "Sustainable development" and sustainability keywords for: a. People, b. Jobs, and c. Companies (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

5.2. Limitations and further considerations

The present paper describes a preliminary analysis of an ongoing project, and thus, the approach is novel and unique, regarding the examination of circular economy data derived from the LinkedIn platform. As a result, there are some limitations to this study. To begin with, the data extraction period is relatively narrow, covering two months, but is considered sufficient enough to test the research question examined, whether LinkedIn can provide information with statistical significance regarding the CE and sustainability relationship. Moreover, the interpretation of the overall results for certain cases (an exception with negative coefficients) requires further analysis to conclude to specific results. Of course, further extractions could provide more data points to perform an extended analysis, with enough data to further investigate more features of this relationship.

Of course, another important limitation of the present study is the source of data itself. To be more precise, the LinkedIn platform hosts a self-selection inclusion of profiles and job posts, from around the world, which means that it provides a sample source and not the population itself in the not digital world. Furthermore, data extraction is not automated and many scientists that acknowledge this source of information as important, try to develop a tool to automate data extraction from LinkedIn (see among others Ecleo and Galido, 2017). An inherent difficulty emerges from the absence of repetition of the data mining if the day passes. This means that data mining that may be performed on a specific day is unique, and one cannot re-capture it on another day.

Another limitation emerges from the fact that the information derived from the LinkedIn platform refers to the occurrence of the keywords, taking into account only the keywords in English, leaving aside a probable language aspect, since some countries have activities in the native language. In our analysis, this was addressed with two arguments. First, we examine the change in the counts, over time. In this way, we take into account a representative sample of the total population, an easily comparable sample, since it has the same properties (namely, the same language of keywords). Second, rendering constant the sample's properties, we may test its change over time. This approach is unique in many ways and the first of its kind, being in its initial stage, we propose an alternative way to explore the dynamic relationship regarding information derived from the LinkedIn platform, comparing the change in the countries' performance over time. More importantly, after detailed data monitoring through test searches, the results indicated that national terms are significantly lower than the international – English term for every country, apart from Sweden. Additionally, we followed the same search methodology as proposed by Tsironis et al. (2022), aiming at the sample's homogeneity. Since there is no text-mining process included in this work, we cannot evaluate the data quality related to companies' descriptions, meaning that companies that include "circular economy" in both languages (English and national) would be double counted. Concluding, our proposed approach does not lack validity, since the sample is always derived by stating the same properties, and the results depict the change of the hits over time, and not a constant picture, giving credit to our results' importance. Based on this, we examined the keyword Circular Economy in Company profiles both in English and in each country's local language and we found that the percentage of national language profiles over the English ones is impressively low for all countries except for Sweden. This gives validity to our paper's approach, as a preliminary analysis.

To address the aforementioned issues, we selected surplus data by including as many keywords as possible. The language is also a limitation as it may restrict the comparability of the data from users with no English profiles. For circular economy and sustainability issues, however, companies tend to have internationally reached profiles (in English) which helped to identify and include them in the analysis. This is necessary as circular economy and sustainability are beyond borders issues to be addressed. Finally, since the LinkedIn platform has global information which can be extracted and compared for different regions of the world, using the methodological approach we propose in this work, we solve the problem of comparability, rendering LinkedIn an important source of information for the examination of the sustainability and circular economy characteristics.

Finally, we must state that this work is a preliminary analysis, and thus the objective of this study is to test the research question mentioned in the introduction of the present paper, whether LinkedIn can provide useful information regarding the CE and sustainability relationship. The 28-EU countries act as a case study due to the same legislation frameworks, and the statistical findings were examined for their validity and usefulness. The language of extraction was the English language solely since practice proved that these notions do not provide important results for the 28-EU countries, with the only exception of Sweden, which can be considered as an outlier. The present paper's results show that LinkedIn can serve as an objective proxy for the investigation of the CE and sustainability performance of countries, providing comparable metrics, since we derive statistically significant results.

6. Conclusion

The contribution of the present work to the theory is, first of all, the validation of the fact that sustainability is a more general subject, being affected in many ways by circular economy practices. By posing a research question, not only do we prove that sustainability as a notion is affected by CE, but we also propose a different methodological approach, through panel data time-series analysis, to capture the effects among the keywords extracted, through the coefficients of the models, also testing their statistical significance. Our proposed approach appears to be very important in revealing the channel of transmission, although its significance, this approach has not been utilized in this specific field of study.

Moreover, the fact that LinkedIn is proved to be an alternative source of objective information, since it is a very popular platform in the business industry, can provide data and make possible nowcasting and forecasting of trends and general interest. This can help decision-makers monitor response when launching new policies and also locate less-performing countries or regions.

The contribution of the present work to the practice is, first of all, the use of an alternative and complementary source of information regarding objective metrics and data, for the sustainability and CE investigation. In this way, the present paper is a novel and unique approach in the field of the circular economy and sustainability, since we derive data from an alternative source, namely LinkedIn, which appears to have an important amount of information, which, based on the authors' current knowledge, has not been utilized in this research field of study, yet. Furthermore, our work proposes also the use of panel time-series analysis as a useful statistical approach for the examination of the relationship between sustainability and CE for many countries. Finally, the present paper proposes as future work and projects, multi-dimensional approaches capable of utilizing information from various sources, resulting in more valid and useful results.

Additional insights can be derived by combining similar data from different platforms or social media (eg. Twitter, Instagram, Tik Tok, and Google trends). Moreover, Other models could also be employed such as GARCH models, capturing the volatility of the LinkedIn profiles in a higher frequency dimension (e.g. daily data), and also other approaches, such as panel-VAR specification and impulse-responses that allows testing whether the circular economy variables affect with greater magnitude the corresponding sustainability variables or the opposite. Of course, further extractions could provide more data points to provide an extended analysis, providing data enough to perform a vector autoregression panel analysis, able to get also the probable spillovers among the keywords examined. These could be subjects of probable future works, extending our results.

CRediT authorship contribution statement

Theodoros Daglis: Formal analysis, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. **Georgios Tsironis:** Data curation, Investigation, Software, Visualization, Writing – original draft, Writing – review & editing. **Konstantinos P. Tsagarakis:** Conceptualization, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rcradv.2023.200151.

Appendix

In this appendix are presented the panel models for the effect of circular economy keywords to sustainability related keywords for People profiles (Table A1), Job posts (Table A2), and Company profiles (Table A3). Tables A1, A2 and A3, detail significance presented in Fig. 4a, b, and c, of the paper respectively.

Table A1
Coefficients for the panel models of people.

Dependent variable	Independent variables	Estimate	Std.Error	*t*-value	*Pr*(>|*t*|)
SDGs	"Circular Business"	0.286	0.506	0.565	0.574
	"Circular Economy"	0.190	0.028	6.889	<0.001
	Circularity	1.266	0.276	4.584	<0.001
Sustainability	"Circular Business"	−48.385	48.137	−1.005	0.318
	"Circular Economy"	17.601	2.622	6.712	<0.001
	Circularity	−41.274	26.294	−1.570	0.120
"Sustainable Development"	Intercept	331.797	1503.545	0.221	0.825
	"Circular Business"	−14.045	18.703	−0.751	0.453
	"Circular Economy"	6.697	0.834	8.026	<0.001
	Circularity	1.558	10.251	0.152	0.879

Table A2
Coefficients for the panel models of jobs.

Dependent variable	Independent variables	Estimate	Std.Error	*t*-value	*Pr*(>|*t*|)
SDGs	Intercept	0.572	20.177	0.028	0.977
	"Circular Business"	−25.141	9.903	−2.539	0.011
	"Circular Economy"	−0.687	0.496	−1.386	0.166
	Circularity	12.886	3.054	4.219	<0.001
Sustainability	"Circular Business"	28.273	22.918	1.234	0.221
	"Circular Economy"	8.677	1.859	4.668	<0.001
	Circularity	31.976	9.979	3.204	0.002
"Sustainable Development"	"Circular Business"	7.471	3.329	2.244	0.028
	"Circular Economy"	0.642	0.270	2.377	0.020
	Circularity	4.185	1.450	2.887	0.005

Table A3
Coefficients for the panel models of companies.

Dependent variable	Independent variables	Estimate	Std.Error	*t*-value	*Pr*(>|*t*|)
SDGs	"Circular Business"	−0.047	0.059	−0.790	0.432
	"Circular Economy"	0.005	0.003	2.067	0.042
	Circularity	0.953	0.128	7.419	<0.001
Sustainability	"Circular Business"	−52.183	39.708	−1.314	0.193
	"Circular Economy"	2.771	1.711	1.620	0.109
	Circularity	2032.645	86.111	23.605	<0.001
"Sustainable Development"	Intercept	86.023	19.002	4.527	<0.001
	"Circular Business"	−1.808	2.350	−0.769	0.442
	"Circular Economy"	0.291	0.120	2.425	0.015
	Circularity	94.180	5.990	15.723	<0.001

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