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Which region and which sector leads the circular economy? CEBIX, a multivariant index based on business actions

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ABSTRACT

The circular economy encompasses a sustainable economic model based on a production, consumption, distribution and maintenance process that reuses as much as possible. In this research, the two-step composite Circular Economy Business Index was created, based on 17 environmental practices that companies have implemented to reduce the generation of waste and emissions and to increase the reuse and efficiency of materials and energy, among other actions. The use of a sample of 26,783 companies from 49 countries and 10 sectors for the period 2014–2019 allowed the aggregation of these initiatives at the country and industry levels. In this sense, our results show less progress in the circular transformation worldwide and can be used in the design of policies aimed at promoting changes in production and consumption systems in specific geographic or industrial contexts.

1. Introduction

Accenture[1] quantified the transition to the circular economy (CE) as being able to lead to global growth of $4.5 trillion by 2030, enhancing the resilience of global economies. Following similar arguments, the European Union plans to recover from the consequences of COVID-19 through *Next Generation EU*, with an allocation of 750,000 million euros, establishing different areas of investment, of which the ecological transition towards a circular model is one of the most powerful. A similar strategy to those of other countries, especially those that have started to be a global manufacturing centre, like China and Japan, has been designed to mitigate the environmental externalities and resource scarcity (Zhu et al., 2010; Tomic and Schneider, 2020).

The CE involves a new economic model that requires changes in the habits of organizations and individuals towards sustainable production, distribution maintenance and consumption systems in line with the objectives of the 2030 Agenda of the United Nations (2015) (Panchal et al., 2021). In other words, the circular transformation requires the abandonment of the take–make–use–dispose linear economy model (Chiappetta Jabbour et al., 2019) in favour of a circular approach to material resources and energy (Geissdoerfer et al., 2017), obtaining economic, social and environmental benefits from regenerating the value of utilized resources (Mavi and Mavi, 2019). The CE requires the instauration of systems that operate in coherence with the energy, water and material cycling principles that, according to Zhu et al. (2010), must comply with eco-systemic self-sustaining properties, which require self-organization capacities, consumption efficiency, the recycling of energy and materials and the reutilization of one company's waste as a resource by another firm.

One of the most pressing challenges to accelerate this transition is measuring the progress of economic circularity as it is extremely difficult to measure the progress of companies in the CE and, even more, to compare their progress at the global level. Academic research has recently become prolific in this regard, and three research groups can be identified based on (i) macro-analysis at the country level focusing on one specific indicator, like resource efficiency; (ii) micro-studies of specific business initiatives; and (iii) meso-analysis encompassing the

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[1] https://www.accenture.com/t00010101T000000__w__/de-de/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_14/Accenture-Circular-Economy-Infographic.pdf.

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Nomenclature

CE	circular economy
CEBIX	Circular Economy Business Index
SMEs	small and medium enterprises
ICB	Industry Classification Benchmark
R&D&I	research and development and innovation
CO_2	carbon dioxide
SOx	sulphur oxide
NOx	nitrogen oxides
CFC-11	chlorofluorocarbons
VOCs	volatile organic compounds
R&D	research and development
NCSRPI	National Corporate Social Responsibility Practices Index
CSR	corporate social responsibility
ICSRPI	Industrial Corporate Social Responsibility Practices Index

combination of the first two groups (Lindgreen et al., 2020). However, the focus of papers implies partial analysis of the complex CE concept.

Therefore, it is possible to affirm that the transition from the economic development linear model to the CE model is a hot topic in the academic, political and business spheres. However, today, a wide academic discussion is taking place on the different ways of dealing with the analysis of the degree of implementation of the CE model, among other reasons because this model involves different initiatives in interrelated ways that are difficult to measure. This makes it an interesting challenge to answer the question "Which country or region and which sector are leading the transformation towards the CE?" and to propose a composite indicator that measures businesses' actions and commitment to ecological transformation.

With this aim, bearing in mind that the effort of enterprise agents for the successful development of proactive environmental practices in support of natural systems is extremely valuable (Zhue et al., 2010), we construct our two-step composite Circular Economy Business Index (CEBIX) using 17 environmental policies and actions that firms have implemented relating to the three scopes proposed by Moraga et al. (2019). This approach allows us to integrate the physical properties of services, products, components and materials; the recovery life cycle approach; and the impacts on the environment, the economy and the society. Later, using multivariate methods, we aggregate these data at the country and industry levels with the aim of identifying the advances in circular transformation in each country and sector. This information should be useful in correcting the delays detected in each of the CE scopes, being adaptable specifically to the countries and industries analysed.

This paper contributes to the previous literature in several ways: (i) using Moraga et al. (2019) proposal of scopes, we advance the analysis of the status quo and the determinants of the level of implementation of the CE with an additive approach moving from the physical properties of the productive activities (products, components and materials) to the circular perspective of the CE and finally to their wider effects on the environment, the economy and the society; (ii) we explain that the improvement in the efficiency of the production process constitutes the basis for the circular transformation, as Robaina et al. (2020) refer to the productivity of the factors. Companies consider short-term assessment when there is a direct relationship between efficiency and economic benefits. The European Union considers this idea in its proposal of the "Circular Economy Package" (European Commission, 2014)[2]; (iii) we consider the whole business system grouped by country and industry following both micro-level and micro-level approaches (Aranda-Usón et al., 2020), adding the implications derived from micro-level studies of the CE, which provides a better understanding of the enterprise actions related to ecological transformation; and (iv) finally, as the regulative policies regarding the CE are not sufficient for successful transformation alone (Ranta et al., 2018), this paper offers very useful information of interest to policymakers, lawmakers, public administrations and other organizations interested in the global sustainable transformation of business.

Methodologically, the use of a two-step process and the CUR matrix decomposition to create the CEBIX allows estimations and predictions with composite indicators that would be much more difficult to carry out with econometric models due to the provision of a measurement of a multidimensional concept in one dimension. With this procedure, it is possible to address the challenge of measuring the CE with a combination of approaches in a dynamic manner, which involves the construction of macro aggregate indicators (at the country[3] and sector levels) based on enterprises' environmental indicators (micro-level).

2. Approaches to the measurement of the circular economy

The CE model aims to contribute to the sustainable development of countries and regions by increasing the offer and use of renewable sources, the replacement of natural resources with secondary materials, the use of clean technologies, more efficient processes and other actions oriented towards the reduction of emissions and waste, decreasing the impact on the environment. It requires the analysis of products' life cycle and the use of materials with a lower environmental impact. It must be understood as a dynamic system that requires the promotion of research to advance the solutions to current and future problems.

However, several authors argue that the definition of the CE is unclear, being created from a fragmented collection of ideas that makes understanding difficult (i.e., Geisendorf and Pietrulla, 2018; Korhonen et al., 2018a). Along this line, Korhonen et al. (2018b) define the CE as "an economy constructed from societal production–consumption systems that maximizes the service produced from the linear nature–society–nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading1-type energy flows. Successful CE contributes to all the three dimensions of sustainable development. CE limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates."

Previous work in the micro-level literature tries to evaluate the transition from the traditional linear business model to a circular one (Aranda-Usón et al., 2020), mainly through the analysis of specific initiatives of technical eco-innovation and the use of renewable materials (Smol et al., 2017; Khan et al., 2020), the study of activities that include the dematerialization of the economy, the use of secondary raw materials and waste recovery (Winkler, 2011), waste treatment and recycling (Chen et al., 2010), ecodesign, eco-innovation and environmental proactivity (Kama, 2015; García-Sánchez et al., 2020a, 2021a; Aibar-Guzmán and Frías-Aceituno, 2021) and other activities in which industrial ecology and/or symbiosis are present (Mathews and Tan,

[2] EC (2014) "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions towards a Circular Economy: a zero waste programme for Europe." COM/2014/0398 final.

[3] In this work, we use the terms national and geographic area interchangeably to refer to countries and regions of which the economic relevance requires an individualized analysis due to their interest.

2011; Winkler, 2011; Wen and Meng, 2015). We identified heterogeneity of actions in convergent institutional environments, such as the case of the European Union countries (Katz-Gerro and López Sintas, 2019), and the use of these initiatives as a differentiation strategy with respect to competitors (Urbinati et al., 2017; García-Sánchez et al., 2020b; Aibar-Guzmán; Somohano-Rodríguez, 2021; Hunka et al., 2021). On the other hand, Elia et al. (2017) establish an index-based taxonomy to determine CE initiatives at the product or organization level, in line with the CE index proposal by Di Maio and Rem (2015) and Di Maio et al. (2017), which focuses on measuring the level of circularity of a product using resource efficiency.

Moraga et al. (2019) offer a classification framework based on the physical properties of technological cycles from the perspective of the CE with three evolutionary scopes. In the first, Scope 0, the physical properties of services, products, components and materials are identified and measured, without a life cycle approach. The effects on technology cycles are then analysed in Scope 1 following a production, commercialization, consumption and end-of-life or recovery life cycle approach (for example, reusability, recyclability or recoverability). Finally, Scope 2, the broadest, includes the effects on the environment, the economy and the society. This evolutionary approach is based on other scholars' view of the CE; for example, Scope 1 is similar to that of Franklin-Johnson et al. (2016) at the macro-level, and there is an emerging literature focusing on the initiatives developed by small and medium enterprises (SMEs) (i.e., Zamfir et al., 2017; Bassi and Dias, 2019: Demirel and Danisman, 2019; Garrido-Prada et al., 2021).

At the macro-level, studies aim to identify the drivers of the circular model, mainly those related to the structure of the economy at the country level, focusing on specific regions and disaggregating the circularity in the use of resources by the type of material (Weisz et al., 2006), resource consumption (West and Schandl, 2013; West et al., 2014; Dong et al., 2017) and waste management and reuse (Awasthi et al., 2018). In general, different studies conclude that the success of CE initiatives depends on various economic factors and financial resources as well as on the influence of the normative and cultural–cognitive pillars as the normative pillar alone is not considered to be capable of driving the necessary change (i.e., Preston, 2012; Dubey et al., 2016; Fei et al., 2016; Zeng et al., 2017; Ranta et al., 2018; Robaina et al., 2020). These approaches allow a comparison between different countries, although they usually consider only one or a few specific indicators and do not undertake a global analysis of the CE.

Thus, academic research has recently become prolific in the study of CE, and two large clusters can be identified based on the macro- or micro-level approach to the analysis (Lindgreen et al., 2020). In addition, it is possible to identify a third cluster, the meso-level scale, which combines the first two groups in the form of company networks, industrial parks or sectoral collaborations (Moraga et al., 2019). However, the current research represents a partial approximation of a multidimensional concept.

In this sense, this paper contributes to the previous literature with the proposal of a global CE index designed with a two-step rigorous aggregation process of enterprises' initiatives. For this, we create a CE index for each firm (micro-level). Later, a composite index is created through the aggregation of the firms' indices at the country and industry levels (macro-level). Our composite index synthesizes a multidimensional concept to facilitate the design of more precise policies and actions aimed at raising the general awareness about the necessary changes in the CE, for society as a whole and, in particular, for firms.

3. The design of the CEBIX

In this section, we propose the methodology of the CEBIX, identify the sample data, describe the operative procedure and the method used in each of the two steps of the process and finally determine the consistency of the CEBIX through a comparative analysis with another index. This approach and the method that we describe below are in line with the compound indicators proposed by authors such as Lenssen et al. (2006), Gjølberg (2009), Halkos and Skouloudis (2016), Skouloudis et al. (2016) and Amor-Esteban et al. (2018a, 2019a, 2019b) for business environmental sustainability.

3.1. Population and sample

Due to the availability of regional and sectoral information for the international comparison, we selected the largest companies worldwide since they are environmentally the most proactive, providing more information about their projects (García-Sánchez et al.,). Hence, we used the Thompson Reuters EIKON database (https://eikon.thomsonreuters.com/index.html) to collect data as it is one of the main platforms containing firms' financial and economic information and it has a specific module concerning environmental, social and governance data on companies' behaviour.

First, we selected all the available environmental variables with information in different years and for a relevant number of companies. Second, we selected those firms that had disclosed information for the selected indicators. The final sample is formed of 26,783 companies in the 2014–2019 period, from 68 different geographical areas and operating in different sectors of activity according to the Industry Classification Benchmark (ICB). In this regard, Table 1 reflects the sample description. However, in the second step of the CEBIX procedure, when we performed the aggregation at the country level, we only utilized 49 geographic regions due to 19 zones having a lower number of firms (below 0.11% of the total sample; see Table 1). Their omission improved the consistency of the results because, with few observations, some countries soared with low scores of the indicator.

3.2. One-step aggregation methodology for the construction of the CEBIX: firms' environmental initiatives

The indicators that were used to determine the circular transformation correspond to 17 firms' environmental initiatives for which information is available to download according to the criteria of temporal frequency and inter-firm observability. The indicators present a dichotomous nature, and they take the value of 1 if the companies have implemented an initiative in relation to the CE and a value of 0 otherwise.

The indicators are synthetized in Table 2 and are associated with the three scopes proposed by Moraga et al. (2019): (0) the physical properties of services, products, components and materials are identified and measured, without a life cycle approach; on this basis, the effects on technological cycles are then analysed in (1) with a production–commercialization–consumption–end of life or recovery life cycle approach (for example, the reusability/recyclability/recoverability indicator); and the broadest, (2), which includes the effects on the environment, the economy and the society.

In general terms, we found that only 26% of the firms have implemented at least one initiative in all of the three scopes; hence, there is limited business commitment, both quantitative and qualitative, in the degree of the scope, to the different business CE initiatives that can be developed.

Looking at the initiatives in Table 2 individually, there are only three that are implanted in 50% of the companies: CE34 and CE36 in Scope 0 and CE41 in Scope 1. They are mainly related to the evaluation of energy efficiency and the control of the impact on the environment, on which Scope 0 is based, as well as the recovery of hazardous waste and wastewater, which are in the CE of Scope 1, in its pursuit of a sustainable economy, with policies to reduce emissions and improve energy efficiency. Hereafter, we found initiatives with a presence between 30% and 40%, CE3, CE17, CE35, CE37 and CE38, which incorporate the life cycle vision based on the development or selection of goods under environmental criteria for their production and transportation, with lower noise pollution, more responsible energy use and so on, and furthermore

Table 1
Sample description.

Panel A. Frequency distribution shows companies by geographical area

	Country	%		Country	%
1	Argentina	0.13%	35	Kuwait	0.14%
2	Australia	7.57%	36	Luxemburg	0.14%
3	Austria	0.31%	37	Macau	0.03%
4	Bahrein	0.07%	38	Malaysia	1.03%
5	Belgium	0.57%	39	Mexico	0.60%
6	Bermuda	0.27%	40	Morocco	0.05%
7	Brazil	1.57%	41	Netherlands	0.82%
8	Canada	5.39%	42	New Zealand	0.71%
9	Cayman Islands	0.03%	43	Nigeria	0.02%
10	Chile	0.49%	44	Norway	0.44%
11	China	2.59%	45	Oman	0.11%
12	Colombia	0.25%	46	Panama	0.01%
13	Cyprus	0.02%	47	Papua New Guinea	0.02%
14	Czech Republic	0.08%	48	Peru	0.16%
15	Denmark	0.59%	49	Philippines	0.45%
16	Egypt	0.19%	50	Poland	0.63%
17	Finland	0.56%	51	Portugal	0.20%
18	France	1.99%	52	Puerto Rico	0.01%
19	Germany	1.83%	53	Qatar	0.20%
20	Gibraltar	0.01%	54	Russia	0.68%
21	Greece	0.29%	55	Saudi Arabia	0.17%
22	Guernsey	0.03%	56	Singapore	1.01%
23	Hong Kong	2.81%	57	South Africa	2.76%
24	Hungary	0.09%	58	Spain	0.93%
25	India	1.92%	59	Sri Lanka	0.02%
26	Indonesia	0.71%	60	Sweden	1.21%
27	Ireland	0.48%	61	Switzerland	1.45%
28	Isle of Man	0.01%	62	Taiwan	2.51%
29	Israel	0.32%	63	Thailand	0.64%
30	Italy	1.07%	64	Turkey	0.52%
31	Japan	8.81%	65	Ukraine	0.01%
32	Jersey	0.04%	66	United Arab Emirates	0.20%
33	Jordan	0.02%	67	United Kingdom	7.22%
34	Korea (South)	2.09%	68	United States	31.70%

Panel B. Frequency distribution shows companies by their sector of belonging

Industry	%
Basic Materials	9.76%
Consumer Goods	10.39%
Consumer Services	12.97%
Financial	22.07%
Health Care	6.32%
Industrial	18.27%
Oil & Gas	6.18%
Technology	6.86%
Telecommunications	2.53%
Utilities	4.19%
Unclassified	0.45%

Table 2
Environmental indicators, their scope and the sampling frequency.

Scope	CE Description	Presence
2	**CE3**. Does the company develop environmental products (i.e. more energy responsible, less noise pollution, etc.)?	*36.3%*
2	**CE38**. Does the company report on initiatives to reduce the environmental impact of transporting its products or its personnel?	*33.3%*
2	**CE46**. The company has invested in environmental research, development and innovation (R&D&I) projects.	*17.8%*
2	**CE45**. The company has invested in environmental capital projects – flat and clean technology.	*15.0%*
2	**CE47**. The firm has implemented ecodesign product strategies.	*12.8%*
1	**CE41**. Does the company report on initiatives to recycle, reduce, reuse, replace, treat or eliminate total waste, hazardous waste or sewage?	*53.1%*
1	**CE35**. Does the company use renewable energy?	*34.8%*
1	**CE40**. Does the company show an initiative to reduce, reuse, recycle, replace, eliminate or offset carbon dioxide (CO_2) equivalents in the production process?	*20.3%*
1	**CE39**. Does the company report on initiatives to reduce, reuse, replace or phase out toxic chemicals or substances?	*11.6%*
1	**CE43**. Does the company report on initiatives to reduce, reuse, recycle, replace or phase out SOx (sulphur oxide) or NOx (nitrogen oxide) emissions?	*9.9%*
1	**CE44**. Does the company report on initiatives to recycle, reduce, reuse or substitute ozone-depleting substances (CFC-11 equivalents or chlorofluorocarbons)?	*8.3%*
1	**CE1**. Does the company develop products or technologies that are used for water treatment and purification or that improve the efficiency of water use?	*3.4%*
0	**CE36**. Does the company have a policy to improve its energy efficiency?	*51.7%*
0	**CE34**. Does the company have a policy to reduce emissions?	*49.7%*
0	**CE17**. Does the company use environmental criteria (ISO 14000, energy consumption, etc.) in the process of selecting its suppliers or sourcing partners?	*40.5%*
0	**CE37**. Does the company have a policy to improve water efficiency?	*34.3%*
0	**CE42**. Does the company report on initiatives to reduce, replace or phase out volatile organic compounds (VOCs)?	*7.5%*

incorporate the use of renewable energies and policies to improve water efficiency.

Among the initiatives with low importance for companies, we found CE40, with 20%, regarding the elimination, replacement or reduction of CO_2 levels in production processes; CE45 and CE46, with 15–18%, oriented towards environmental research and development (R&D) and clean technology; CE47, with 13%, referring to ecodesign product strategies; and CE39, with 12%, focusing on initiatives to eliminate, replace or reduce chemicals or toxic substances.

The comments on the results in the previous paragraph suggest that firms are proactive in including environmental initiatives aimed at reducing consumption and increasing the efficiency of the production process and the value chain (Scopes 0 and 1). These initiatives have a positive effect on circular transformation, but they are also the actions that have the most direct relationship with the achievement of direct economic benefits (i.e., cost reduction and profitability increases). The importance of the factors' productivity is crucial, and many business leaders should consider their adoption to increase their company's growth and profitability (Robaina et al., 2020). Hence, Scopes 0 and 1 should be considered from a short-term perspective. On the contrary, regarding Scope 2, the results could indicate that companies adopt long-term initiatives that suggest a differentiation strategy with respect to their competitors through the inclusion of products and sustainable logistics, results that should be in line with those obtained in previous papers (Urbinati et al., 2017; García-Sánchez et al., 2020b; Aibar-Guzmán; Somohano-Rodríguez, 2021; Hunka et al., 2021).

Lastly, among the indicators of less popular initiatives, those with a presence under 10% are CE42, CE43 and CE44. They are initiatives to eliminate, replace or reduce more specific gases, such as VOCs, SOx, NOx and substances that deplete the ozone layer. In this sense, it is necessary to take into account the fact that the production and importing of these chemicals is controlled by the Montreal Protocol, so such a point in the factors is perhaps not the most representative. Furthermore, CE1, on the development of products or technologies for the treatment and purification of water, is shown to be the least important indicator, with 3% of the firms. This may be due to the fact that, except for companies dedicated to water treatment, firms are currently more focused on reducing their consumption than on other processes aimed at reuse.

In Fig. 1, it is possible to observe the interrelationships between the enterprises' environmental initiatives according to the scope. In this sense, it is apparent that the initiatives implemented at the company level, in general, are linked to a specific scope, although, in the case of Scopes 0 and 1, they could be linked to a specific initiative of another scope. Thus, for example, we can see that companies that have promoted initiatives in Scope 0, related to reducing emissions, increasing energy efficiency and water consumption, are also promoting the use of renewable energy (a Scope 1 initiative). In the case of companies of

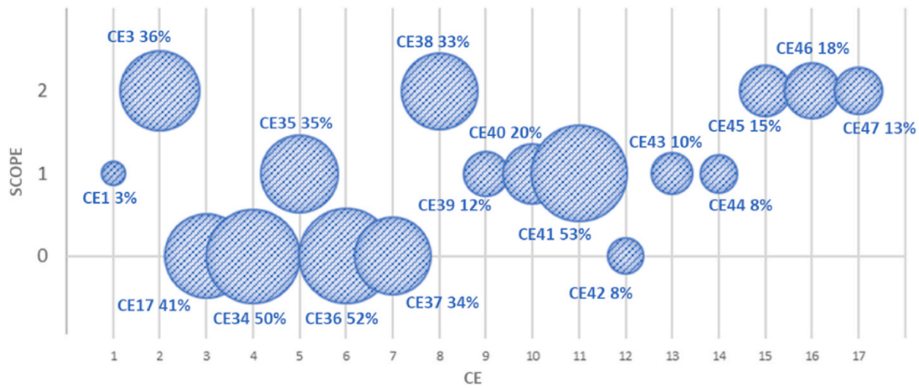

Fig. 1. Identified presence of and interaction between CE initiatives according to their scope.

which the contribution to circular transformation is linked to Scope 1, their initiatives are aimed at reducing, reusing, replacing or phasing out toxic chemicals, substances, CO_2 and so on. On the other hand, companies that contribute to the CE in Scope 2 adopt initiatives related to the use of clean technologies and investment in R&D&I, eco-innovation and eco-design. These results confirm why the analyses carried out on the CE so far have focused on specific initiatives, like eco-innovation, waste treatment and recycling and the use of renewable materials (Chen et al., 2010; Kama, 2015; Smol et al., 2017; García-Sánchez et al., 2020a, 2021a; Khan et al., 2020; Aibar-Guzmán and Frías-Aceituno, 2021).

3.3. Two-step aggregation methodology for the construction of the CEBIX: CUR decomposition

The objective of this step is to propose an index that measures the advances in the CE by aggregating data at the country and sector levels based on the initiatives promoted by firms. To achieve this objective, we used the CUR matrix decomposition (Mahoney and Drineas, 2009), which is applied to extensive data sources in which the interest emphasizes the selection of the individuals or variables with greater relevance (Su et al., 2012). In our case, we built a matrix of 17 rows (the CEs) and 26,873 columns (the full sample of firms) to estimate a value or score for each company known as "leverage", which indicates its level of influence within the data set. This value allowed us to identify the most proactive companies in the CE transformation: those with the greatest presence in the 17 CEs studied.

Researchers usually make use of dimension reduction techniques with these types of data, especially principal component analysis, the objective of which is to reduce or even eliminate noise and to extract the relevant information from a reduced number of components to explain the general behaviour in the data set. This type of method is successfully applied in multiple disciplines, such as biology (González-Narváez et al., 2021), genetics (González-García et al., 2020), economics (Amor-Esteban et al., 2018b) and psychology (Vega-Hernández et al., 2017), among many others.

However, the components are always linear combinations of all the original variables, and they are not easily interpreted as latent factors of the original processes (Mahoney and Drineas, 2009). Alternatively, the CUR matrix decomposition constitutes a low-rank approximation expressed in a small number of rows and/or columns of the original matrix, and the probability of selecting these rows and/or columns is proportional to their degree of influence in relation to the "leverage" achieved. As can be seen in Fig. 2, in this research, we were not looking for that low-range approximation; actually, we were interested in the "leverage" or influence statistic, which has exactly the same meaning and interpretation as those associated with each individual and serves as an identifier of atypical data in the context of linear regression (Bodor et al., 2012).

This is a technique with a wide range when working with data from different fields and obtains very good results for composite indices (Amor-Esteban et al., 2020), unsupervised learning for simultaneous selection of samples and characteristics (Li et al., 2018) and pedagogical statistical models (Barahona, 2018), and its use is increasing. We use open-access software, a package in R (Bodor et al., 2012), and Dynamic CUR (Barahona et al., 2019).

Formally defined as a data matrix of order $I \times J$, where I represents the number of rows and J the number of columns, the *CUR* matrix decomposition of X is given by $X_{I\times J} \approx C_{I\times c} U_{c\times r} R_{r\times J}$. C is a reduced number of columns and R a reduced number of rows of matrix X,

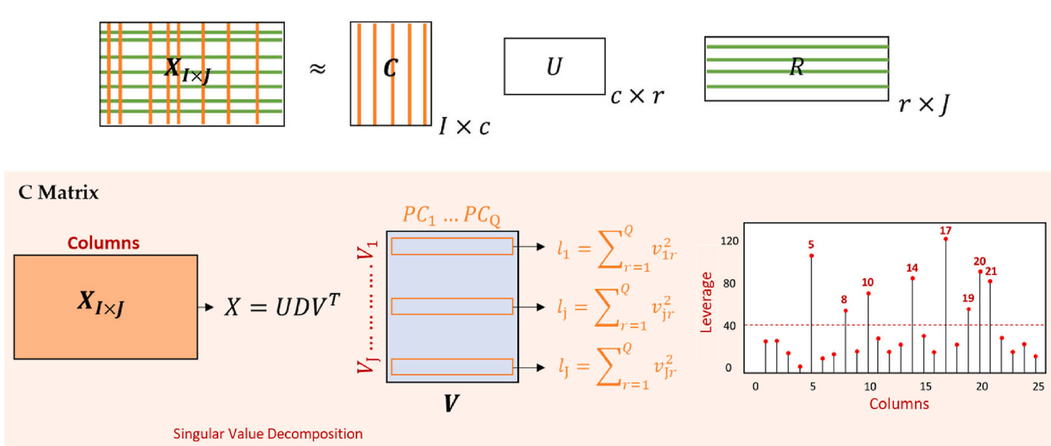

Fig. 2. Calculation of the leverage for each column for the creation of the C matrix (Amor-Esteban et al., 2020).

respectively, while U is a small matrix that is carefully constructed in such a way as to guarantee effectively that the matrix product CUR approaches X satisfactorily. This method is an alternative in the decomposition of matrices as it is interpretable in terms of the original data and it works with a small proportion of columns – matrix C– and a small proportion of rows – matrix R. The reduced number of rows and/or columns is selected based on the "leverage", and these values represent an indicator that allows the measurement of the influence of the *j-th* column or the *i-th* row, according to the interest of the researcher. It must be understood as a measure that quantifies the influence that variables and/or individuals have on the agglomeration of groups with greater discriminatory power. These values depend on input parameter k, that is, the number of dimensions to retain, and, as would be expected, those rows and columns with the highest scores are more likely to be selected (Bodor et al., 2012).

In formal terms, if v_j^ξ is the *j-th* element of the ξ right eigenvector of matrix X, the normalized statistical influence "leverage" is given by:

$$l_j = \frac{1}{k}\sum_{\xi=1}^{k}\left(v_j^\xi\right)^2$$

For all $j = 1,\ldots,J$, these weights coincide (except for scale) with the diagonal elements of the projection matrix of the k right eigenvectors of matrix X.

3.4. A comparative analysis of methodologies for consistency

To guarantee the consistency of the composite indicators created in this paper, it is recommendable to determine whether there is any relationship between the CEBIX indicator and the other relevant analysis initiatives. Accordingly, we conducted a comparison with: (i) the National Corporate Social Responsibility Practices Index (NCSRPI) indicator proposed by Amor-Esteban et al. (2019a, 2019b), consisting of an analysis of 1,459 international listed companies from 29 different countries in developed economies and considering 22 corporate social responsibility (CSR) practices for quantifying the sustainable commitment of those companies following different approaches: the environment, stakeholders, human rights, ethics and employees; and (ii) the Industrial Corporate Social Responsibility Practices Index (ICSRPI) indicator, proposed by Amor-Esteban et al. (2018a), which is based on a sample of 2,789 companies worldwide belonging to the 10 industries established by the ICB, the commitment of which is evaluated using 28 sustainability initiatives categorized into both the social and the environmental dimension.

These indices follow similar methodological processes structured in seven phases: (i) the development of a theoretical framework for the national or industrial institutional context; (ii) the selection of CSR practices that represent a high level of quality according to their relevance, timeliness, accessibility and analytical consistency; (iii) the imputation of missing data; (iv) the elimination of those practices that reduce the quality of the theoretical model; (v) the standardization of the data; (vi) the weighting of those practices that make up the final index through the standardized regression weights of a confirmatory factor analysis of the simplified model, checking the reliability of all the selected CSR practices and the validity of the construct; and (vii) the aggregation of the CSR practice scores using a weighted sum to derive country and industry CSR scores. The comparison allowed us to determine whether there is a relationship between the CE initiatives developed and the CSR practices at the region and industry levels.

Likewise, with the aim of reinforcing the CEBIX indicator, we used the HJ-biplot method (Galindo, 1986) to demonstrate the relevance of the different environmental initiatives as this method allows low-dimensional representations of multivariate data. With this method, we represented the regions (or sectors) of the study as points and the 17 environmental indicators, and we added the CEBIX indicator as a vector in the same plane. In this way, those vectors that form acute angles will correspond to positive correlations, and those points that are close to each other will show similar characteristics. All the processes and representations performed in the HJ-biplot analysis were implemented using the software MultBiplot (Vicente-Villardón, 2010).

Having established the methodology to be used in the two stages, the creation of the CEBIX and the procedure to ensure its consistency, we present the results achieved in the following sections.

4. Results derived from the construction of the CEBIX at the country level

4.1. Ranking and composite indicator

The first results of the aggregate indicator show the distribution of the leverage for all companies, calculated by applying the CUR decomposition to the data matrix, which consists of 26,783 companies measured on 17 environmental indicators. Fig. 3 shows the leverage values calculated for each of the companies in the study. The leverage provides information about the statistical influence of each company over the total data set, and, focusing on sustainability, those companies with greater commitment are prominent. Hence, it is possible to observe that the majority are concentrated in the black area in the figure, and only a few, around 2%, detach themselves from the rest and are reflected in the upper part of the figure; these companies are considered the leaders in this commitment, although their identification is not the objective of our investigation.

We added the leverage per company in the determination of the score at the country and sector levels and analysed the degree of development of the CE. With the z score transformation, we obtained the scores at the country level, erasing companies from regions with a small number of companies (below 0.11%; see Table 1), making a total of 49 geographical areas, to give more consistency to the results. The indicator scores are shown in Table 3, in which the first column represents the country's position in the environmental ranking, with France being the country with the highest score and Qatar obtaining the lowest, and the CEBIX column provides the score achieved for the indicator. Analysing the countries' order by the index values, it can be seen that the first positions are held by European countries and Japan, while, at the end of the list, there are many countries with important mining resources and China, which is only three positions behind Canada and four behind the United States (36th position). In prominent positions are India (16), Turkey (17) and Brazil (18), just ahead of the United Kingdom (19), Greece (20) and Ireland (21). Russia (29), Mexico (28), Colombia (27), South Africa (26) and Israel (25) occupy the average positions in the table.

These results present similarities to and divergences from the evidence presented in previous studies. In this sense, our paper is similar to several papers that provide evidence that the success of CE initiatives

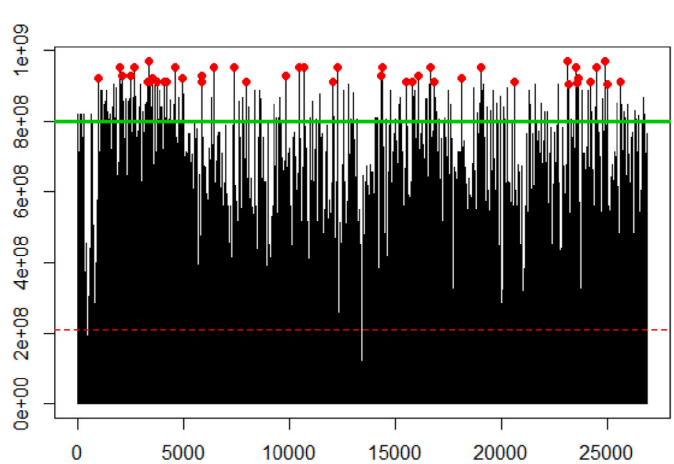

Fig. 3. Leverage by company, CUR matrix decomposition.

Table 3
Circular Economy Business IndeX – National/geographic zone (CEBIX-N).

Ranking	Geographic zone	CEBIX	Ranking	Geographic zone	CEBIX
1	France	2.274	*26*	South Africa	−0.221
2	Finland	2.207	*27*	Colombia	−0.245
3	Spain	1.635	*28*	Mexico	−0.310
4	Germany	1.541	*29*	Russia	−0.361
5	Portugal	1.267	*30*	Philippines	−0.396
6	Sweden	1.241	*31*	Singapore	−0.400
7	Netherlands	1.218	*32*	Indonesia	−0.444
8	Japan	1.076	*33*	Chile	−0.448
9	Austria	1.053	*34*	Malaysia	−0.531
10	Denmark	0.952	*35*	Hong Kong	−0.627
11	Italy	0.925	*36*	United States	−0.718
12	Norway	0.696	*37*	Canada	−0.747
13	Switzerland	0.584	*38*	Poland	−0.766
14	Belgium	0.552	*39*	Saudi Arabia	−0.948
15	Korea (South)	0.537	*40*	China	−0.964
16	India	0.528	*41*	Australia	−1.003
17	Turkey	0.466	*42*	Bermuda	−1.069
18	Brazil	0.384	*43*	New Zealand	−1.079
19	United Kingdom	0.375	*44*	Kuwait	−1.241
20	Greece	0.364	*45*	Egypt	−1.308
21	Ireland	0.194	*46*	United Arab Emirates	−1.334
22	Luxemburg	0.087	*47*	Peru	−1.602
23	Taiwan	0.074	*48*	Argentina	−1.622
24	Thailand	0.055	*49*	Qatar	−1.758
25	Israel	−0.141			

depends on the availability of financial resources and the efficacy of the institution (i.e., Preston, 2012; Dubey et al., 2016; Fei et al., 2016; Zeng et al., 2017; Ranta et al., 2018; Katz-Gerro and López Sintas, 2019; Robaina et al., 2020). Moreover, we found evidence that firms located in European Union countries show a heterogeneous and greater commitment to the CE due to operating in institutional environments in which there is a common strategy, the *European Green Deal*, which has been reinforced with a post-covid *Next Generation EU* recovery plan, targeting circular transformation through a package of measures – structural funds, research and innovation financing programmes and so on – to help European businesses and consumers in the transition to a more sustainable economy. Furthermore, following the consideration of Robaina et al. (2020) that the more circular the economy is, the fewer natural resources are used, the resource productivity will be higher than that based on services' activities. However, this could be one of the reasons for Spain and Portugal, with high rates of gross domestic product (GDP) based on tourism, appearing at the top of the list, with Germany, Finland and France, in our results.

On the other hand, in the Latin American countries, due to structural reasons, the critical situation of their economy, the importance of the material-intensive sectors (i.e. forestry and mining industries) for the GDP or the legislative limitations to the generation of positive incentives or coercive mechanisms, progress in the CE is non-existent. In addition, surprisingly, the country ranking partially confirms the effort made in global manufacturing countries, like China and Japan, with the aim of mitigating the environmental consequences of the economic activity (Zhu et al., 2010; Tomic and Schneider, 2020).

4.2. Comparative analysis

The CEBIX indicator scores prove, once again, much greater engagement in the European countries than in the rest of the world. To determine whether there is any relationship with other sustainability initiatives that would allow us to contrast the consistency of the CEBIX, we undertook a comparison with the NCSRPI indicator proposed by Amor-Esteban et al. (2018a, 2019a). The comparison allowed us to affirm that there is a strong non-linear relationship between the CE initiatives developed at the regional level and the NCSRPI, with a highly significant correlation of 0.561** (see Fig. 4). These results highlight the convergence between CSR practices and CE initiatives. However, the NCSRPI encompasses different practices – environment, human rights, employees, stakeholders and ethics – while the CEBIX focuses on environmental initiatives; hence, some regions that are more focused on certain practices do not adjust to the model as most of them do. Recent papers observe that socially responsible companies are not always environmentally responsible as well (Ferri and Pini, 1019).

Additionally, to demonstrate the relevance of the different initiatives with respect to the CEBIX indicator, we represented a subspace created using the 17 indicators and the constructed indicator through an HJ-biplot (see Fig. 5). The factorial planes 1–2 absorb a total of 75% of inertia, the majority due to the first factorial axis (66%), and the index shows a quasi-perfect relationship with the axis.

All the CEs have a strong relationship (acute angles) with their indicator, although, in general, it is true that some are somewhat more distanced, and these correspond to indicators with a low presence/importance in the companies. Thus, in the upper plane, we found a sequence of scopes with CE42 (7%) on the elimination of toxic substances or volatile organic compounds, CE1 (3%) on the development of products that improve the efficiency of water use and CE39 (12%) and CE47 (13%) regarding eco-design products; the companies that stand out are Japan, Korea (South), Taiwan and Sweden. In the lower half-plane, we found CE43 (10%) and CE44 (8%), concerning the reduction or elimination of SOx and NOx emissions or gases that deplete the ozone layer, and CE37 (34%) and CE41 (53%), related to water efficiency and wastewater treatment policies; southern European countries, such as Spain, Portugal and Italy, are prominent. These indicators, which are less related to the aggregate environmental index, show their direction towards water efficiency and the elimination or reduction of toxic substances.

The CEs nearest the environmental aggregate indicator focus on initiatives to reduce the environmental impact of production and transportation activities and emissions as well as the application of environmental criteria to the supply process. These are CE17 (40%), CE34 (50%), CE38 (33%) and CE40 (20%), with only European countries – Finland, France, Germany and so on.

We also found a relationship between CE3 (36%) on the development of environmental products and CE46 (18%) relating to environmental R&D projects and between CE35 (35%) on renewable energies, CE36 (52%) referring to policies to improve energy efficiency and CE45 (15%) regarding environmental capital projects, basically for Denmark and Norway.

These results suggest that the European Union institutional environment improves the development of initiatives associated with Scopes 0 and 1, while, in all its countries, there is similar evidence to that obtained by Katz-Gerro and López Sintas (2019); however, firms in specific countries could adopt additional initiatives as a differentiation strategy (Urbinati et al., 2017; García-Sánchez et al., 2020b; Aibar-Guzmán and Somohano-Rodríguez, 2021; Hunka et al., 2021). The global manufacturing countries, like Japan and Taiwan, are adopting a mixed scope of initiatives, fomenting environmental practices linked to different phases of environmentally sustainable products' life cycle, manufacture and use. These initiatives are associated with the laws and instruments that are being developed in these countries, mainly promoting the use of alternative materials to plastic.

4.3. Dynamic analysis

In the dynamic analysis, we considered the aggregation of the leverage by company and country to obtain two types of rankings: first, the scores per year for the period 2014–2019, and, second, the CEBIX score; these are presented in Table 4. In addition, we added two columns at the end of the table with the position of each country in the ranking according to the CEBIX in the year 2019.

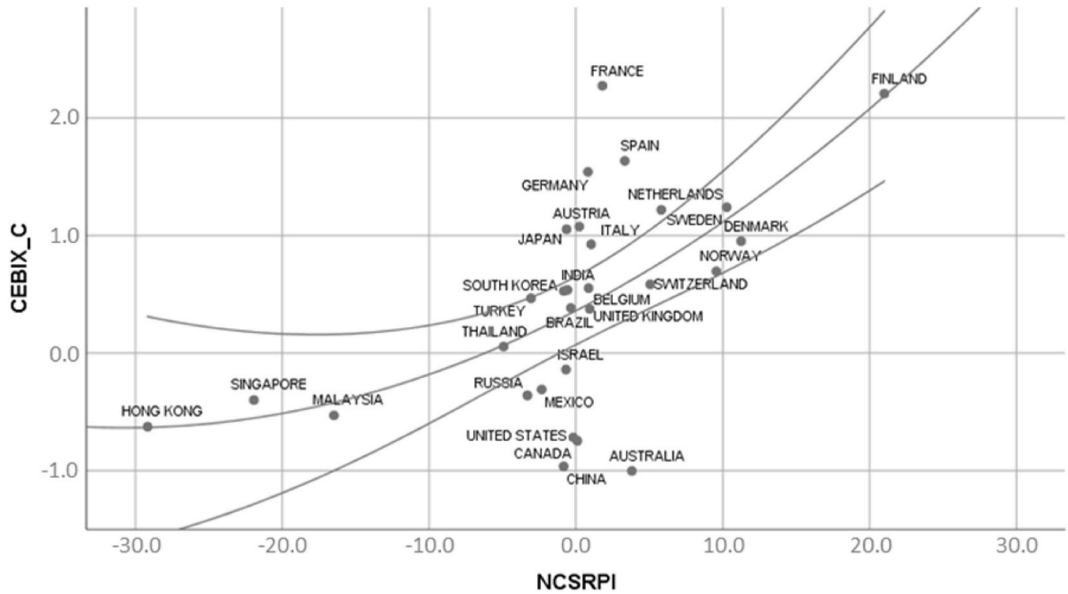

Fig. 4. Non-linear relationship between the environmental indicator and the NCSRPI.

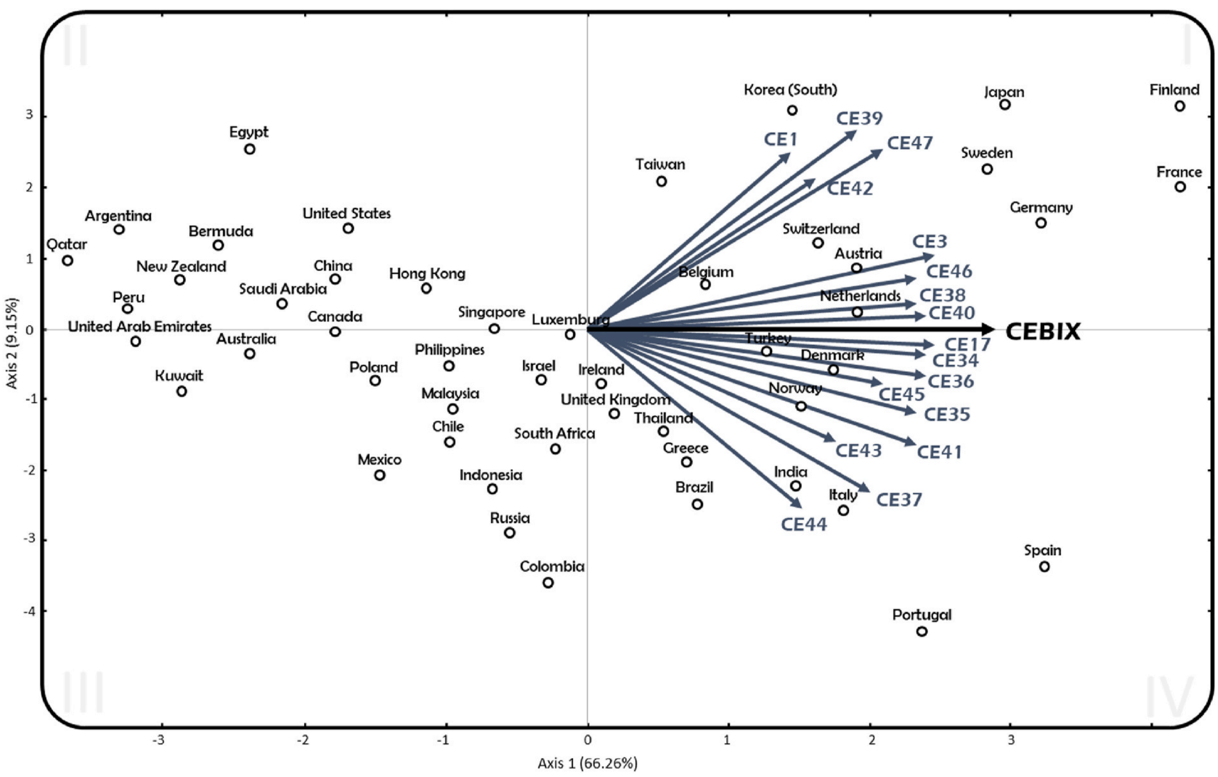

Fig. 5. Factorial planes 1–2 of the HJ-biplot of the CEBIX and the 17 CEs.

The dynamic analysis of the 2014–2019 period reveals the stability of the scores obtained by most countries, with small variations in their positions but not exceeding a change of ±5 positions. In general terms, most environmentally sensitive countries maintained their positions, with exceptions, such as Luxemburg (falling 12 places) and Norway (−5), which show a loss of relevance in the last year. In the same way, other countries, such as the Philippines (losing 14 places), Israel (−8) and Saudi Arabia (−7), stand out for losing positions, while, on the contrary, some less sensitized countries improved their valuation notably. In these cases, we can highlight Mexico (rising 15 places), Hong Kong (+10), Singapore, Ireland (+7), Canada and Kuwait (+6). If the adoption of the CE is considered as a process, we can deduce that the most advanced countries progress to a lesser extent than the less sensitive countries. This information is shown graphically in Fig. 6.

In sum, the institutional environment of the European Union and Japan is improving the development of the EC in a stable, continuous but low manner, leading the circular transformation in the analysed period. On the other hand, companies from specific countries, such as Mexico, Hong Kong and Singapore, are rapidly promoting changes in the linear economic model that prevails in their environments.

Table 4
CEBIX dynamic evolution at the national level.

	2014	2015	2016	2017	2018	2019	CEBIX	Ranking CEBIX	Ranking 2019
France	2.19	2.20	2.31	2.31	2.24	2.04	2.274	1	2
Finland	2.03	1.98	2.12	2.29	2.31	2.13	2.207	2	1
Spain	1.72	1.60	1.51	1.57	1.66	1.44	1.635	3	4
Germany	1.44	1.63	1.62	1.54	1.44	1.25	1.541	4	6
Portugal	1.16	1.23	1.14	1.31	1.27	1.90	1.267	5	3
Sweden	1.45	1.49	1.48	1.02	0.96	0.93	1.241	6	9
Netherlands	1.15	1.00	1.01	1.45	1.30	1.13	1.218	7	7
Japan	1.05	1.01	1.03	1.05	1.03	0.96	1.076	8	8
Austria	1.16	1.08	0.69	0.96	0.94	1.34	1.053	9	5
Denmark	0.85	0.90	0.95	0.98	0.82	0.89	0.952	10	10
Italy	0.91	0.86	0.80	0.93	0.90	0.81	0.925	11	11
Norway	1.19	1.19	1.04	0.33	0.30	0.30	0.696	12	17
Switzerland	0.46	0.42	0.52	0.59	0.54	0.69	0.584	13	15
Belgium	0.53	0.49	0.43	0.57	0.44	0.58	0.552	14	16
Korea (South)	0.60	0.57	0.51	0.35	0.50	0.27	0.537	15	19
India	0.36	0.63	0.54	0.52	0.54	0.30	0.528	16	18
Turkey	0.26	0.14	0.19	0.55	0.76	0.79	0.466	17	12
Brazil	0.43	0.27	0.32	0.34	0.37	0.16	0.384	18	20
United Kingdom	0.55	0.56	0.66	0.17	0.14	0.10	0.375	19	22
Greece	0.04	0.36	0.44	0.34	0.48	0.02	0.364	20	23
Ireland	0.05	0.05	0.06	−0.16	0.38	0.71	0.194	21	14
Luxemburg	0.19	0.39	0.26	−0.34	−0.62	−0.55	0.087	22	34
Taiwan	−0.27	−0.31	−0.03	0.26	0.45	−0.11	0.074	23	26
Thailand	0.09	−0.10	−0.09	−0.04	0.14	0.14	0.055	24	21
Israel	−0.37	0.01	−0.36	0.03	−0.04	−0.52	−0.141	25	33
South Africa	−0.43	−0.42	−0.32	−0.18	−0.09	−0.18	−0.221	26	28
Colombia	−0.35	−0.36	−0.13	−0.09	−0.43	−0.49	−0.245	27	32
Mexico	−0.25	−0.50	−0.47	−0.26	−0.48	0.75	−0.310	28	13
Russia	−0.53	−0.53	−0.51	−0.42	−0.27	−0.15	−0.361	29	27
Philippines	−0.42	−0.53	−0.56	−0.39	−0.33	−1.48	−0.396	30	44
Singapore	−0.77	−0.70	−0.45	−0.33	−0.29	−0.01	−0.400	31	24
Indonesia	−0.38	−0.61	−0.54	−0.62	−0.39	−0.32	−0.444	32	30
Chile	−0.68	−0.32	−0.21	−0.16	−0.78	−0.79	−0.448	33	36
Malaysia	−0.76	−0.74	−0.70	−0.53	−0.43	−0.25	−0.531	34	29
Hong Kong	−0.83	−0.90	−0.77	−0.73	−0.56	−0.04	−0.627	35	25
United States	−0.17	−0.19	−0.14	−0.73	−1.03	−1.08	−0.718	36	40
Canada	−0.81	−0.85	−0.86	−0.82	−0.79	−0.49	−0.747	37	31
Poland	−0.89	−1.00	−0.97	−0.73	−0.61	−0.65	−0.766	38	35
Saudi Arabia	−0.75	−0.78	−0.53	−1.21	−1.08	−1.52	−0.948	39	46
China	−1.15	−1.19	−1.15	−0.83	−0.66	−1.00	−0.964	40	39
Australia	−1.04	−1.16	−1.13	−1.00	−1.04	−0.87	−1.003	41	37
Bermuda	−1.25	−1.27	−1.17	−1.78	−1.77	−1.52	−1.069	42	47
New Zealand	−0.28	−0.55	−0.54	−1.25	−1.26	−1.08	−1.079	43	41
Kuwait	−1.45	−0.88	−1.40	−1.29	−1.32	−0.98	−1.241	44	38
Egypt	−1.53	−1.52	−1.46	−1.27	−1.16	−1.52	−1.308	45	48
United Arab Emirates	−1.05	−1.09	−1.61	−1.33	−1.33	−1.23	−1.334	46	42
Peru	−1.48	−1.51	−1.60	−1.69	−1.62	−1.52	−1.602	47	49
Argentina	−1.99	−2.05	−1.94	−1.36	−1.64	−1.29	−1.622	48	43
Qatar	−1.99	−2.05	−1.90	−1.71	−1.70	−1.51	−1.758	49	45

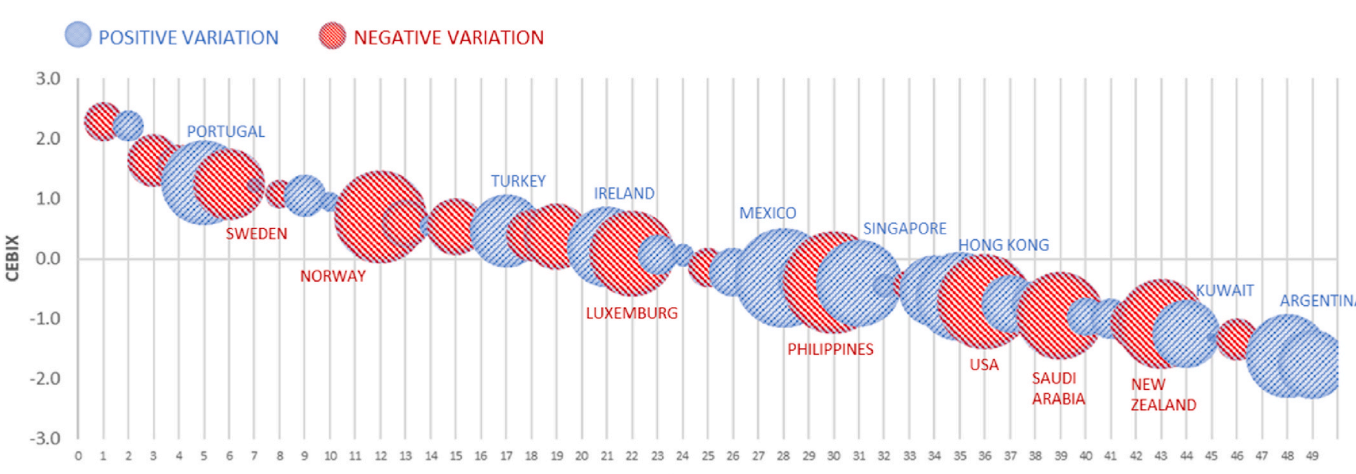

Fig. 6. The CEBIX's dynamic evolution at the country level in the period 2014–2019.

5. Results derived from the construction of the CEBIX at the industry level

5.1. Ranking and composite indicator

Next, we proceed to the aggregation of the leverage by companies according to their activity in the ICB. We obtained the CEBIX scores at the sector level (Table 5). The utilities sector is in the first position, that is, the one with the greatest environmental commitment; and the financial sector is in the last one. The other columns refer to the score obtained by each sector as well as the ICSRPI scores and their environmental version.

The results suggest that the sector of activity is a relevant explanatory factor of EC development due to the presence of significant differences. Firms in the utilities, consumer goods, industrial and basic materials sectors have the potential to play a critical role in the development of the CE because many of the technological developments that could accelerate circularity are within their sphere of operations.

5.2. Comparative analysis

Like the analysis at the country level, we compared the CEBIX indicator at the sector level with the ICSRPI indicator. The two indicators showed similarities in the order of commitment of the industries. They have a significant and strong relationship, especially in the environmental version, with a correlation coefficient of 0.743* (see Fig. 7). This correlation is higher than the national version because both indicators represent firms' environmental commitments at the sector level, the CEBIX for environmental initiatives focusing on the CE and the ICSRPI for environmental CSR practices. Therefore, the higher correlation between the two environmental indicators is an indicator of the CEBIX's consistency.

Then, we interpreted the index scores and their relationships, again with the 17 CEs, using the HJ-biplot method, in which the 10 industries and their scores for the 17 CEs are represented in a two-dimensional subspace. We added the CEBIX so that we could determine its most important relationships with CEs. The factorial plane formed by the first two axes collects 71% of the information (Fig. 8).

The main ideas are, in the first place, that CE3 on environmental product development, CE36 on energy efficiency policies and CE41 on initiatives for waste management are the closest to the CEBIX. Utilities and consumer goods are the sectors that are the most committed to the CE.

Second, if we focus on the first quadrant, the concerns revolve around emissions and water use, and we found that the utilities, industrial and basic materials sectors are the most involved in improving these aspects. The CEs involved are CE34, emission reduction policies, CE37, water efficiency policies, and CE46, environmental R&D projects, for which the industrial sector has great importance. CE1, regarding the development of products for water efficiency, CE40, concerning CO_2 emissions, CE43, focusing on SOx and NOx emissions, and CE45, considering clean technology projects, are presented as priorities of the basic materials sector and to a lesser extent the oil and gas sector. This sector is only concerned about these last indicators.

Third, in the lower half-plane, in the fourth quadrant, we found the consumer goods sector. It occupies the second position in the CEBIX, and the companies in this sector focus their commitment on CE17, the use of environmental criteria for their supply, CE35, the use of renewable energies, CE38, the reduction of the environmental impact of transportation, CE39 and CE44, the reduction of toxic substances and gases that deplete the ozone layer, and CE47, ecodesign product strategies. They take great care of the environmental impact of their emissions in production and transportation. To a lesser extent and focusing only on the latter CE38, CE39 and CE47, we located the telecommunications sector and, one notch below it, the technology sector.

Finally, it should be noted that consumer service companies and the health care and financial sectors present the lowest scores of the CEBIX, so those companies are the ones with the lowest commitment to the CE.

These results confirm that the CE initiatives that firms are boosting in each industry are highly related to their specific activity, explaining why sectors favour innovations in the composition and efficiency of materials, electrification, hydrogen production and carbon capture and use, among others, while other sectors focus on eco-design, the reduction of materials and waste, the reuse of products and the recycling of waste; in this sense, the valorization of these is gaining increasing boom to obtain other subjects. The sectoral specialization in relation to the CE is similar to that evidenced in several studies on other areas of sustainability, such as the sustainable development goals (van der Waal et al., 2021).

Table 5
Circular economy business IndeX - industry (CEBIX-I).

Ranking	Industry	CEBIX	ICSRPI	ICSRPI_ENV
1	Utilities	1.339	4.478	1.434
2	Consumer goods	1.169	1.609	0.615
3	Industrial	0.688	2.085	0.587
4	Basic materials	0.593	4.520	1.480
5	Telecommunications	0.346	−0.654	−0.637
6	Technology	0.083	0.032	−0.075
7	Oil & gas	−0.571	3.185	0.653
8	Consumer services	−0.976	−3.659	−1.099
9	Health care	−1.190	−0.103	−0.328
10	Financial	−1.480	−3.645	−0.964

5.3. Dynamic analysis at the sectoral level

We performed the aggregation by companies of the leverage based on the sectors and, once again, we obtained two rankings, the scores per year and the CEBIX. These are shown in Table 6, in which the last columns correspond to the position of each country in the ranking according to the CEBIX in 2019. Except for specific sectors, the position is maintained in 2019, although with different trends.

More specifically, in Fig. 9, it can be observed that the consumer goods, industrial, technology and health care sectors lose intensity in relation to the initiatives developed to promote the CE transformation in the 2014–2019 period, and this evolution takes place since 2016. On the contrary, the basic material and telecommunication sectors improved their position, showing greater commitment to the implementation of environmentally integrated policies and practices.

In sum, firms are developing CE initiatives that are strongly associated with their activity. At the industry level, the utilities, consumer goods and industrial sectors are leading the circular transformation, but only utilities are achieving it in a stable, continuous and low manner. Their efforts are oriented towards material, energy and emissions. During the period analysed, basic materials and telecommunications promoted more circular practices associated with the technologies that they use in their production systems.

6. Conclusions

In this paper, the composite index CEBIX was created to determine the level of CE development at the country and industry levels according to firms' efforts. In general terms, only 26% of companies have implemented an initiative, so the first conclusion is that there is very limited commitment of companies to the CE and it is necessary to boost initiatives that improve its development at the micro-level.

France and the utilities sector led the transformation towards the CE in the period 2014–2019. The first positions are occupied by European countries and Japan. These countries, together with Korea (South), Taiwan and Sweden, present the most intense relationship with a complete sequence of indicators (Stages 0, 1, and 2) with CE 42, CE1, CE39 and CE47 for the elimination of toxic substances or volatile organic compounds, the development of products to improve the efficiency of

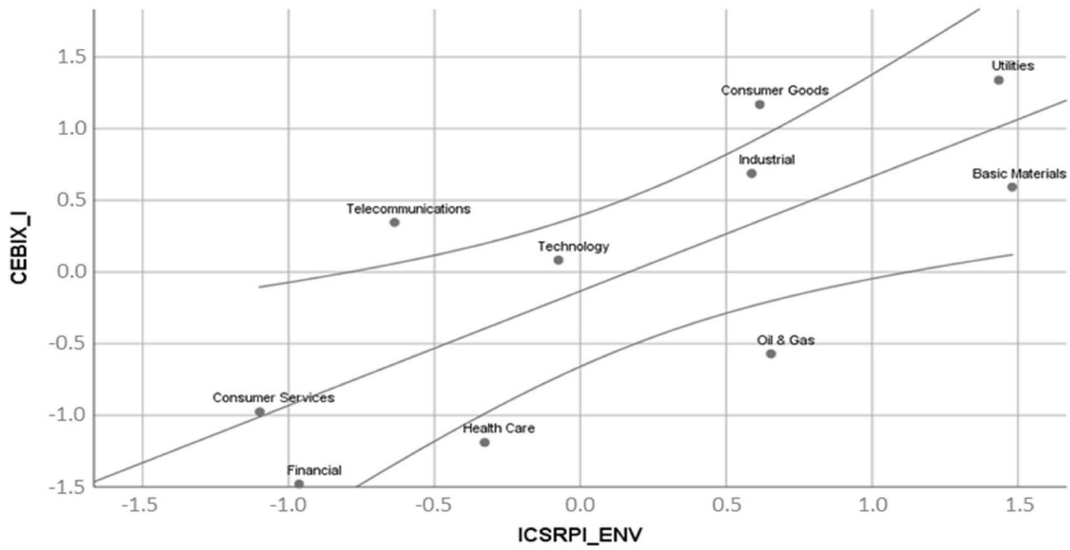

Fig. 7. The linear relationship environmental indicator and the ICSRPI.

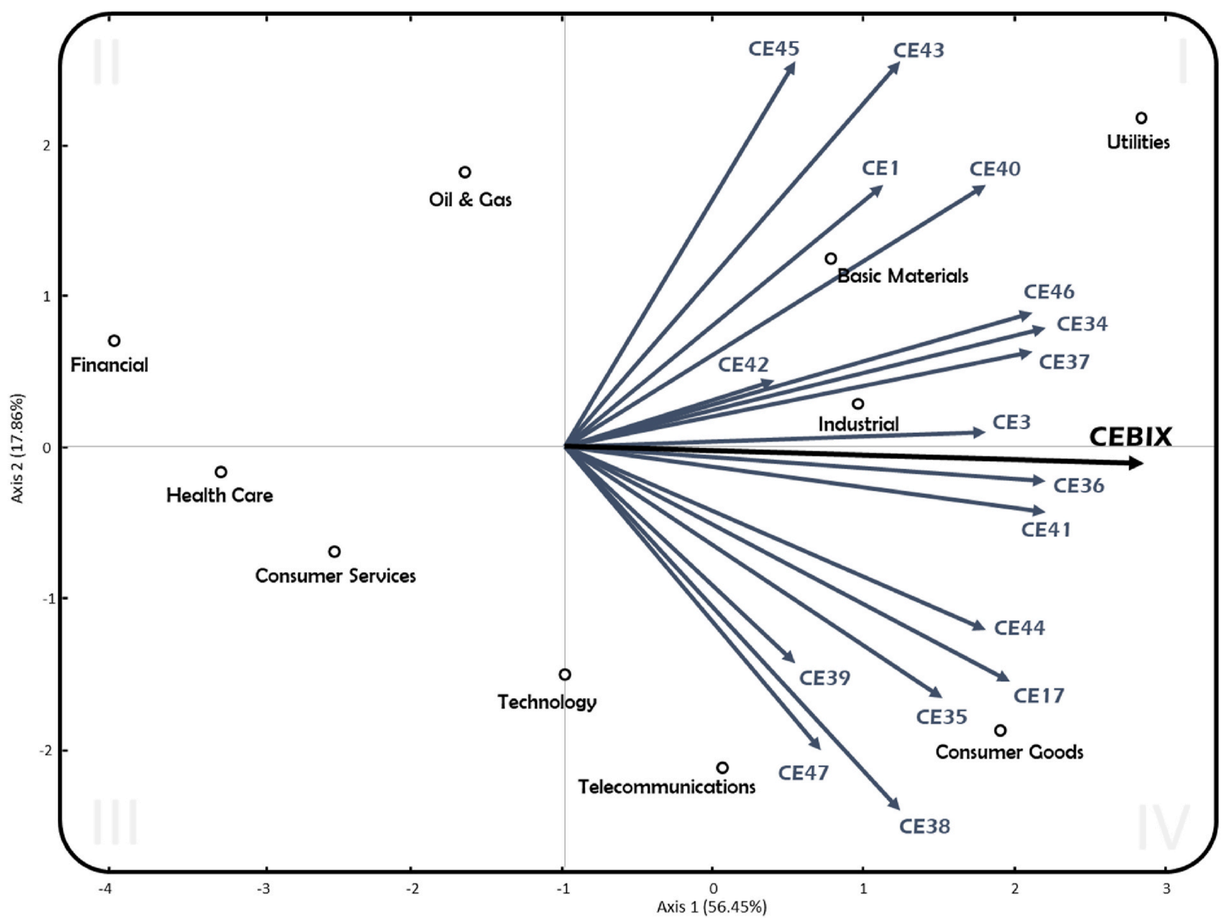

Fig. 8. Factorial planes 1–2 of the HJ-biplot of the CEBIX and the 17 CEs.

water use and the development of eco-design products. In the second step, we found CE3 for the development of environmental products, CE46 for environmental R&D projects, CE35 for renewable energy, CE36 for energy efficiency improvement policies and CE45 for projects and environmental capital, mainly in Central European countries. The aggregate environmental CE is located with initiatives to reduce the impact on production and transportation as well as emissions and the application of environmental criteria in supply processes that correspond to CE17, CE34, CE38 and CE40, also in European countries, like Finland, France and Germany.

From the perspective of dynamic analysis, we observed important stability in the period studied. In general terms, the most sensitized countries maintain their positions, with exceptions such as Luxemburg or Norway, which show a loss of relevance. On the opposite side,

Table 6
CEBIX dynamic evolution at the sector level.

	2014	2015	2016	2017	2018	2019	CEBIX	Ranking CEBIX	Ranking 2019
Utilities	1.26	1.27	1.16	1.33	1.34	1.36	1.339	1	1
Consumer goods	1.25	1.22	1.25	1.04	1.04	1.10	1.169	2	2
Industrial	0.79	0.84	0.87	0.73	0.52	0.37	0.688	3	5
Basic materials	0.19	0.29	0.37	0.64	0.74	1.02	0.593	4	3
Telecommunications	0.08	0.02	0.11	0.42	0.60	0.50	0.346	5	4
Technology	0.57	0.54	0.51	0.13	−0.22	−0.67	0.083	6	7
Oil & gas	−0.87	−0.88	−0.84	−0.60	−0.30	−0.30	−0.571	7	6
Consumer services	−1.08	−1.10	−1.08	−1.00	−0.88	−0.84	−0.976	8	8
Health care	−0.58	−0.63	−0.82	−1.17	−1.45	−1.32	−1.190	9	10
Financial	−1.61	−1.57	−1.54	−1.52	−1.38	−1.22	−1.480	10	9

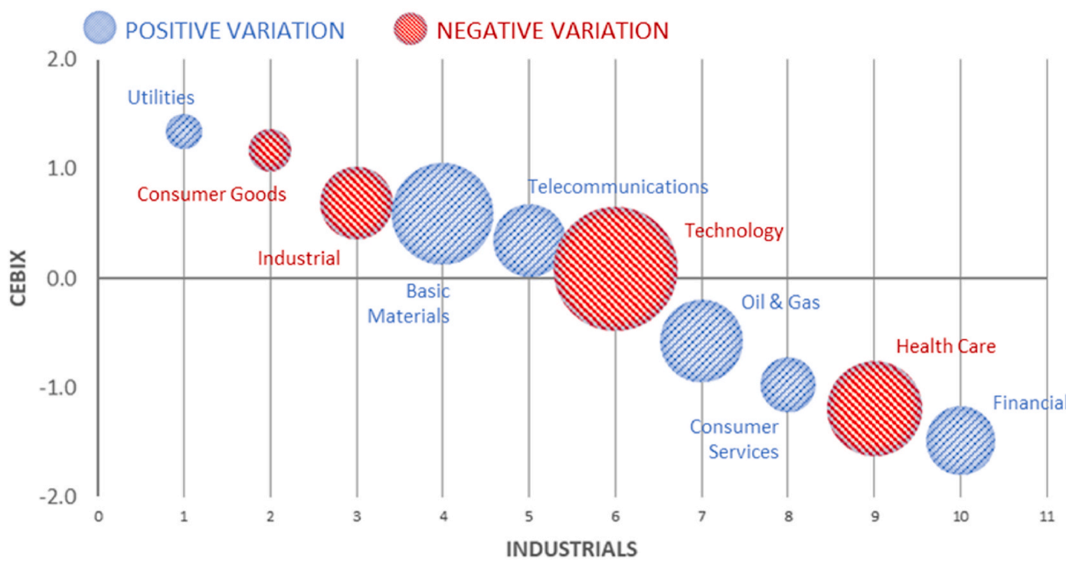

Fig. 9. The CEBIX's dynamic evolution at the sector level in the period 2014–2019.

Mexico, Hong Kong, Singapore, Ireland, Canada and Kuwait move in the other direction, gaining sensitivity in recent years.

In this sense, regarding the initiatives that the public administrations are promoting in the US and Japan to favour circular transformation as a whole or with respect to specific initiatives, our results confirm the evidence of the relevant role that the institutional environment plays, and it is possible to recommend that other countries adopt the European regulatory frameworks as a success model.

By sectors, utilities and consumer goods are the sectors that are most committed to the CE in CE3, for the development of environmental products (Scope 2), CE36, for energy efficiency policies (Scope 0) and CE41, for waste management (Scope 1). In contrast, consumer service, health care and financial firms are less committed to the CE. From a dynamic perspective, there are no major variations in the ranking of sectors, only highlighting the improvement of one position in telecommunications and basic materials. These results indicate that higher commitment to the CE is strongly associated with firms' activity, suggesting that the initial stage at the company level, to boost the CE, must be associated with their production systems, either by promoting the reduction of materials, energy or water or by including clean technologies, eco-innovation and eco-design strategies.

Our paper presents important contributions from the theoretical and practical points of view. First, we offer a new approach to the analysis scopes of the EC transition; second, we consider the improvement of the efficiency and the profitability of the process as the basis for the circular transformation; third, the analysis considers three levels: micro, meso and macro; and fourth, we highlight the importance of complementary policies. Thus, from a practical point of view, the CE is viewed as a pillar of post-pandemic recovery based on the idea that circular business models allow more diverse, sustainable, employment-intensive and recurring forms of income, being more flexible in the face of possible disruptions, such as those caused by the COVID-19 pandemic. In this sense, the results of the CEBIX made it possible to quantify the progress made to date and identify the necessary changes, serving as a starting point for designing policies and concrete measures that promote the transition to the CE and tackle the socioeconomic problems derived from the pandemic.

Finally, the composite indicator is subject to limitations. As mentioned, some indicators have their origin in the breadth of the CE concept, especially regarding its scope and its potential impacts on consumer habits, quality of life, health, job creation and well-being, among others. Parameters that should be considered in future studies, favouring the creation of more complete indices to determine the degree of circular transformation of today's society, should include the degree of progress in the transition towards the CE with respect to three phases: the first focusing on the evaluation of results and similar actions; the second referring to the transition processes themselves; the third adopting a final approach to the incorporation of elements of the CE or of strategies that contemplate complete cycles; and the fourth concerning the impacts of these strategies on quality of life, job creation and other outcomes. Additionally, the extension of the time period under analysis may allow the impact derived from the efforts made by certain public institutions in their post-COVID-19 recovery plans to be identified.

Conflict of interest and authorship conformation form

All authors have participated in the conception and design, or analysis and interpretation of the data; drafting the article or revising it critically for important intellectual content, and approval of the final version.

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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.

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