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Progress towards sustainable activities: Principal component analysis (PCA) of SMEs in the European Union

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Abstract. This study examines small and medium-sized enterprises (SMEs) in the European Union (EU) and their openness to circular economy practices. A cross-section of European SMEs is evaluated using data for the EU-27 taken from the Euroflash Barometer 549 (SMEs, resource efficiency, and green markets). The aim of this study is to reveal the relationship between various circular economy activities within the European Union. This objective is accomplished by means of the statistical technique known as principal component analysis (PCA), which involves the categorization of variables into dimensions. The analysis pointed to two categories of circular economy activities. According to the research results, up to 93% of SMEs implement at least one circular economy activity. SMEs that adopt strategies for the efficient use of environmental resources, particularly in water conservation, also employ energy-saving measures. PCA identified a second group prioritizing modular architectures, environmentally benign materials, and recurrent resource use. Notably, businesses focusing on water conservation appear to prioritize sustainable product design the least. In contrast, those incorporating circular economy principles into product design and manufacturing also tend to emphasize recycling and reuse.

Keywords: circular economy, sustainability, sustainable activities, SMEs

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1. INTRODUCTION

Globalization, rapid population increase, and technological advancement have all fueled the development of production and consumption patterns that upset the natural balance (Tang et al., 2020). Climate change, environmental pollution, and widespread socioeconomic disintegration are among the most troubling modern issues. As human activity is the primary cause of the problem, humanity needs to work toward resolving these conflicts by rethinking the current production models and market economy in a way that is both intelligent and sensitive. The United Nations has embraced this argument at the highest level. A number of actions have been taken by institutions, societies, and organizations in an effort to address the problem and achieve more sustainable development (Valverde & Avilés-Palacios, 2021). Many stakeholders at various levels, including governments, academia, and businesses, have supported the UN's Sustainable Development Goals (Dantas et al., 2021).

The critical importance of sustainability has become undeniable due to growing environmental concerns and the rapid depletion of natural resources. Concurrent advancement in the economic, social, and environmental domains is essential for achieving success via sustainable development (Peyravi et al., 2024; Toušek et al., 2025). Even though economists throughout the world have been working for a long time to predict the most accurate economic development, crises typically occur rather suddenly (Gajdosikova & Vojtekova, 2024). In the context of intensifying globalization and economic interdependence, economic and institutional determinants are crucial in the analysis of a country's environmental performance (Negrete-Cardoso et al., 2022). In recent decades, the rapid development of the global economy, which has been driven by the excessive consumption of natural resources and policies that are not sustainable for development, has resulted in significant socioeconomic and environmental issues (Velenturf & Purnell, 2021). It has become a key priority for companies be able to survive worldwide competition and meet local goals, to achieve economic growth standards at any cost. During this process, narratives on development frequently disregard and overlook the irreversible harm produced by developmental hazards to natural entities (Soto, 2025). The idea of green growth has become more important in EU economic policy as a result of the increasing threat of climate change (Batlles-delaFuente et al., 2024). In light of recent events, there is a growing need to identify new methods of putting sustainable development principles into practice, although sustainable development is not exactly a new topic (Ranf et al., 2024). When resources are used and managed well, and when their constituent parts produce results, the national economy benefits. Contrarily, when resources are not fully utilized, their effectiveness and utility are severely limited (Nagy et al., 2024; Petrakova & Karascony, 2024).

Activities and measures aimed at sustainable development and the circular economy are often diverse, and their management in companies does not have a defined concept. The objective of this study is to identify the relationship between a variety of circular economy initiatives that have been implemented within the European Union. It is essential for identifying circular activities that are mutually supportive and, conversely, those that are not mutually supportive. Identifying these prevailing trends will make it possible to understand and manage the research gap, where these activities are not mapped in such a comprehensive way at the European Union level. Identifying these preferences and trends enables to understand how SMEs operating in the European Union environment are moving in the field of circular economy and thus set up unified strategies for optimizing these processes. The prevalence of certain strategies and determining their mutual relationships is also beneficial for finding out which categories are dominant and, conversely, identifying groups that SMEs are not targeting. The prevalence of certain strategies and the determination of their mutual relationships are also beneficial for finding out which categories are dominant and, conversely, identifying groups that SMEs are not moving toward. Focusing on this issue may allow to

understand which activities can create a synergistic effect together, but also, identify which activities in the SMEs environment are not being carried out sufficiently.

It is necessary to analyze this issue from a broad concept and therefore the paper is divided as follows. The literature review section covers significant topics such as the definition of the circular economy, its activities, and a comparison between the circular economy and the linear economy system. The methodology section outlines the critical stages necessary for the precise execution of PCA. In addition, it describes in detail the data used in this study, their description, and the importance of proper summarization of the selected data and statistical-mathematical methods. The results section presents the analyses performed and their detailed description with regard to the researched issue of the analysis of circular economy activities in the SME environment of the European Union. Comparable investigations that have been carried out in this area are the subject of the Discussion section. A comparison of the findings with those of other research is also included in this part. The purpose of this comparison is to identify similarities and differences between the studies that were identified worldwide. There is a summary of the key results that are included in the Conclusions, along with a determination of the impending problems and limits that had an effect on the research.

2. LITERATURE REVIEW

Through the process of manufacturing, natural resources are transformed into trash, which is the foundation of the contemporary linear economy. The old approach, in which products are made and then thrown away as garbage, is having a negative impact on the environment (Garcés-Ayerbe et al., 2019). In the "take-make-dispose" method of industrial production, inputs are removed, mixed, processed, consumed, and disposed. Despite the strong institutionalization of linearity, producers, governments, and scholars are becoming more interested in switching to a circular economy model in order to leave the linear paradigm (Hartley et al., 2020; Potkány et al., 2024). It is the responsibility of stakeholders to guarantee that resources circulate and recirculate within the economy, according to the circular economy framework, which conceptualizes the economy as a closed system (Katz-Gerro & Lopez Sintas, 2019; Zhidebekkyzy et al., 2022). The normal process of supply chains, similar to that of a linear economy, makes use of the raw materials for the industrial manufacturing process (Neves & Marques, 2022), and then, after consumption, converts those materials into waste. Nevertheless, according to Sariatli (2017), the linear economy model is not capable of effectively regulating the supply and demand balance in the case of the exploitation of natural resources. Circular economy is an economic model that aims to make efficient use of resources in order to minimize waste, maintain long-term value, eliminate primary resources, and create a closed-loop system for products, parts, and materials within the realm of environmental protection, as well as socio-economic benefits (Morseletto, 2020;Gedvilaite & Ginevicius, 2024).

An developing idea, dynamic capabilities are a company's capacity to change and react to surroundings. Within the framework of a circular economy and digitalization, dynamic capabilities are very essential for businesses to remain competitive and meet evolving consumer wants and aspirations (Sălăgeanu & Bejinaru, 2023). The contemporary corporate landscape is marked by instability, hypercompetition, and swift technical advancements, posing significant challenges for SME management (Belas, 2023). The emergence of digitalization has offered several opportunities for both providers and consumers by supplying a substantial amount of data for their utilization (Gallo et al., 2024; Peukert & Reimers, 2022). In order to ensure that internal processes are in alignment with new technologies, successful automation implementation requires a meticulous analysis (Balcerzak and Valaskova, 2024). In order to address competition or established consumer requirements, firms in dynamically evolving market sectors respond to new impulses and environmental effects (Gajdosikova et al., 2024). Sustainable learning entails facilitating educational experiences that enhance consumers' comprehension of professional obligations, competencies,

and motivations (Dabija et al., 2023; Vătămănescu et al., 2019). In light of this, the concept of a circular economy refers to the process of constructing a system with the objective of maximizing the utilization of resources and minimizing the impact on the environment, all while ensuring that the welfare of individuals is not neglected. To summarize, when considering a product, it is necessary to take into account its whole life cycle, beginning with the design phase and ending with the point at which it can no longer be utilized (Vinante et al., 2021).

The circular economy indices have emerged as a valuable resource for facilitating the development of policies that provide information that mitigates environmental pressures and impacts. Nevertheless, the practical implementation of highly dimensional data that identifies numerous circular economy indicators is impractical. The transition to a circular economy necessitates not only the modification of a specific activity, but also systemic changes in industry, social components, energy, transportation, agriculture, and more. Different approaches and time frames for transitioning to a circular economy are the result of the unique principles and limitations of each economic sector, as well as the specificities of each country in the EU. The research by Sverko Grdic et al. (2020) indicate that there is a correlation between economic development and circular economy indicators. However, there are certainly numerous instances of the circular economy concept being implemented globally, with exceptional outcomes, from which it is feasible to gather essential knowledge. The circular economy concept should not be implemented solely by depending on state interventions and subsidies. Starting with the classification and recycling of refuse, energy conservation, and energy conservation, companies can implement their own transition initiatives. The research conducted by Androniceanu et al. (2021) indicates that the circular economy is a viable strategic alternative. exercisable in order to foster sustainable economic development and establish a competitive advantage. The structure helps SMEs to have a thorough awareness of the circular economy change. To reach sustainability and raise competitiveness, it underlines the need of using lean management techniques, circular business models, and creative ideas. By means of the micro level insights (strategy, resources, management, and innovation), SMEs may create concrete plans for adopting circular economy concept inside their companies.

The circular economy is a development priority of the European Union and is a component of the EU industrial strategy. However, there is no index that is commonly acknowledged to quantify these activities on a macro level, despite the fact that Europe is a proponent of the circular economy idea or concept (Alfaro Navarro & Andrés Martínez, 2024). The study by Avdiushchenko & Zając (2019) has focused on recent trends in CE indicators as a monitoring tool for supporting European regional development policies. Its results are meant to enable regional authorities to monitor the development towards circular economy transition thereby enabling smart and sustainable development. Current circular economy monitoring in Europe does not address such important issues as tracking changes in consumption and production patterns, the geographical dimension impacted by circular economy strategies and social, economic and cultural changes generated by reorientation towards circular economy-based regional development.

The relationship between economic development and sustainable development is also a frequently debated topic. Bolcarova & Kolosta (2015) noted that it does not seem that high economic growth is associated with sustainable development tendencies. A complete transformation of the internal structure of these economies toward sustainability could be the solution to this issue. The adoption of varying development strategies by some of the latter in order to transition their economies to a circular economy is one of the causes of the varying levels of advancement of individual countries toward circular economy (Mazur-Wierzbicka, 2021). The study used a combination of Data Envelopment Analysis (DEA) and PCA, a combined PCA-DEA evaluation model. The metrics for quantifying circular economy indicators has been developed using a variety of methods, such as the PCA and PROMETHEE (de Oliveira et al., 2021) and the Multiple Correspondence Analysis (Parchomenko et al., 2019). Therefore, in order to achieve universal adoption of the circular economy, it is necessary to make concerted efforts to reinvent all production plans and business models from a circular perspective.

3. METHODOLOGY

The European Commission is responsible for conducting a series of opinion polls that are referred to as Eurobarometer. For a more comprehensive comparison, the data is gathered through opinion polls conducted in 27 different member states of the European Union. Specifically, this study focuses on Flash Eurobarometer 549: SMEs, Resource Efficiency and Green Markets (European Commision, 2024).

The sample was chosen from an international business database Eurostat (European Commision, 2024) and was representative of the size and sector of companies in each country. The survey was conducted on a sample of 14,049 companies. Table 1 presents the frequency distribution of the variables of interest within the sample of European SMEs.

Table 1

Sample description

Category	Frequency (%)
Firm size	
1 to 9 employees	93.6
10 to 49 employees	5.4
50 to 249 employees	0.8
250 or more employees	0.2
Business establishment	
Before 1 January 2016	76.3
Between 2016 and 2023	21.1
After 1 January 2023	2.6
Turnover	
Up to €100,000	26.3
€100,001 - €500,000	35.6
€500,001 - €2,000,000	23.3
€2,000,001 - €10,000,000	9.0
More than €10,000,000	5.8
Business activity	
Products	22.5
Services	45.8
Both products and services	31.7
Sector	
Manufacturing (C)	8.6
Industry (B/D/E/F)	17.3
Retail (G)	24.5
Services (H/I/J/K/L/M)	49.6

Notes: NACE Classification: B: Mining and quarrying. C = Manufacturing. D = Supply of electricity, gas, steam, and air conditioning. E = water supply, sewerage, waste management, and cleanup. F = construction, G = wholesale, retail commerce, motorcycle and car maintenance, H = transportation and storage, I = accommodation and food service operations, J = information and communication. K = financial and insurance operations, L = real estate activities, and M for professional, scientific, and technological activities.
Source: own processing according to European Commision (2024)

SMEs are important drivers of economic development because they create jobs, regulate income distribution, and foster innovation (Purwandani & Michaud, 2021). SMEs have the potential to play a role in minimizing their effect on the environment, protecting biodiversity, and renewing natural resources. The following research questions serve these purposes:

RQ1: What environmental behavior patterns are present in small and medium-sized businesses in the European Union?

RQ2: Is it possible to identify the main categories of circular economy measures implemented by SMEs in the European Union?

The relationship between SMEs and sustainability in Europe is not an isolated issue. It depends on a wide range of variables, including competitiveness, profitability, financing accessibility, and sustainable business models. A considerable disparity that hinders the EU's future competitiveness trajectory is created by some businesses being eco-friendly while others are traditional and energy-intensive SMEs in order to remain realistic in the EU context (Okolo et al., 2023). The survey contribute to the efforts of the Commission to assist SMEs in becoming more environmentally friendly and to boost their long-term competitiveness.

PCA serves as one of the primary statistical techniques for analyzing and verifying these basic data. However, before conducting PCA, it is essential to verify the suitability and relevance of performing factor analysis. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, developed by Kaiser, Meyer, and Olkin (Kaiser, 1970), is used to assess whether a data sample is appropriate for factor analysis. KMO examines the adequacy of the sample by analyzing the proportion of variance among variables that might be common variance. It is calculated based on correlations and partial correlations between variables, as follows:

$$KMO_j = \frac{\sum_{i \neq j} R_{ij}^2}{\sum_{i \neq j} R_{ij}^2 + \sum_{i \neq j} U_{ij}^2} \quad (1)$$

where, R_{ij}^2 are the squares of the correlations between the variables i and j; U_{ij}^2 are squares of partial correlations between variables. The applicability of the factor analysis is demonstrated by the KMO value, which indicates how high it is. When the KMO values are less than 0.50, it indicates that the factor analysis is not appropriate (Shrestha, 2021; Guttmanm, 1954).

The Bartlett's test of sphericity is used to determine whether or not the correlation matrix between variables is appropriate for factor analysis. A test is performed to determine whether the correlation matrix is identical to the unit matrix, which means that it determines if correlations between the variables are significant. Before conducting factor analysis, it is utilized to evaluate the appropriateness of the data; if it is seen to be significant, it indicates that there are correlations between the variables that are suitably strong. In the process of determining whether or not to use factor analysis, it is frequently combined with the KMO test (Bartlett, 1950). Bartlett's test verifies the following hypotheses:

- The null hypothesis (H_0): The correlation matrix is equal to the identity matrix, meaning no significant correlations exist, thus factor analysis in inappropriate.
- The alternative hypothesis (H_1): The correlation matrix significantly differs from the identity matrix, indicating the presence of substantial correlations suitable for factor analysis.

The formula for Barlett's test of sphericity is as follows:

$$X^2 = -\left(n - 1 - \frac{2p + 5}{6}\right) ln\,|R| \quad (2)$$

where, p = number of variables, n = total sample size and R = correlation matrix.

To assess the overall strength of the relationship among variables, the determinant of the correlation matrix, denoted as |R|, is computed. Bartlett's test of sphericity is one of the most common ways to check if data is ready for advanced statistical methods that aim to reduce the number of dimensions and analyze the structure of data.

It is essential for policy and practice to comprehend how a circular economy might lessen the environmental stresses caused by economic activity (Korhonen et al., 2018). Individual measures are always tied to individual selected categories, such as the total number of employees, the year of establishment of enterprises, the annual turnover of enterprises, business activity and finally the NACE sector in which enterprises conduct their business activities. Table 2 shows the proportion of sample SMEs implementing each circular economy technique.

Table 2

Percentage of businesses implementing circular economy activities

Category	SW (%)	SE (%)	RE (%)	SM (%)	GS (%)	MW (%)	SRW (%)	R (%)	DP (%)
Firm size									
1 to 9 employees	48.4	65.9	23.5	56.3	33	65.3	21.6	47.9	28.9
10 to 49 employees	49.5	68.6	31.8	59.9	37.7	71.2	32.9	50.7	30.7
50 to 249 employees	53.3	73.8	41.1	60.5	42.3	70.1	39	50.8	31.4
250 or more employees	47.8	78.3	43.5	65.2	47.8	73.9	43.5	56.5	39.1
Business establishment									
Before 1 January 2016	49.8	67.1	24.5	56.4	32.5	65.3	22.2	47.7	29
Between 2016 and 2023	45.7	63.8	22.3	57.6	36.9	67.2	21.8	49	28.7
After 1 January 2023	33.3	60.7	31.3	54.3	32.5	68.5	31.9	54.4	35.7
Turnover									
Up to €100,000	50.4	65.6	18.3	54.8	30.2	59.9	15	44.6	26.1
€100,001 - €500,000	49.7	65.4	23.1	58.6	35.9	68.1	21.3	49.4	30.1
€500,001 - €2,000,000	47.9	69.7	25.2	57.3	34.6	67.7	31.8	49.2	32.5
€2,000,001 - €10,000,000	46.3	66.4	36.7	57.2	35.8	72.5	26.5	50	30.6
More than €10,000,000	48.2	63.9	38.5	55.1	26.9	65.8	27	44.1	20.7
Business activity									
Products	50.5	66.9	21.6	51.9	31.6	63.9	25.2	54.4	24.7
Services	46.9	65.6	23.3	56.5	30.2	63.4	16.8	42.2	24.6
Both products and services	50.1	66.3	27.5	60.3	39.5	70.9	28.6	52.8	39.1
Sector									
Manufacturing (C)	52.5	66.1	24.6	63.9	35.9	71.8	34.6	51.3	35.5
Industry (B/D/E/F)	45.5	62	26.8	61.3	31.9	71.3	27.5	51.3	36.4
Retail (G)	52.3	68.9	23.6	57.1	36.7	66.8	26.2	52.3	30.4
Services (H/I/J/K/L/M)	47.1	66.2	23.4	53.3	31.7	62.2	16.6	44.3	24.6

Notes: SW (Saving water); SE (Saving energy); RE (Renewable energy); SM (Saving materials); GS (Green suppliers); MW (Minimising waste); SRW (Selling residues and waste to other companies); R (Recycling); DP (Designing products)
Source: own processing according to European Commision (2024)

Data for this research were obtained from the Flash Eurobarometer survey (European Commission, 2024), which focuses on sustainable and circular economy efforts in businesses of all kinds and sectors throughout the European Union. The following methodological steps are performed:

1. The study identified primary sustainability activities, such as the development of environmentally friendly products, the use of environmentally friendly suppliers, waste reduction, recycling, energy and water conservation, and other sustainability initiatives.
2. The appropriateness of factor analysis was assessed using the KMO Measure of Sampling Adequacy and Bartlett's Test of Sphericity. Because PCA is contingent upon the existence of significant correlations between variables, these tests were instrumental in determining whether such relationships were present in the dataset.

3. To reduce dimensionality and identify corporate-accepted sustainability measures, PCA was implemented. The optimal number of components to retain was determined using the Scree Plot and Kaiser Criterion.
4. The study explored how the size of a company influences the extent to which it adopts circular economy-related practices. A heat map was utilized to visually compare businesses of different sizes, illustrating the degree to which SMEs adopt sustainability concepts.

4. EMPIRICAL RESULTS AND DISCUSSION

It is necessary to verify the assumptions for performing PCA. The results of the KMO test of selection adequacy and Bartlett's test of sphericity indicate the appropriateness of using factor analysis. The KMO Measure of Sampling Adequacy is at 0.686, indicating that the data matrix is acceptable for factor analysis. Bartlett's test of sphericity is significant ($p < 0.001$), which means that the null hypothesis of a unit correlation matrix was rejected. This confirms that there are significant correlations between the variables and factor analysis can be applied.

Table 3

KMO and Bartlett's Test of Sphericity results

KMO Measure of Sampling Adequacy	**0.686**	
Barlett's Test of Sphericity	Approx. Chi-Square	**15.828**
	df	**36**
	Sig.	**<0.001***

Source: Authors' results. * indicates significance level at 0.05 level.

The Scree Plot, Figure 1, indicates that it is recommended to keep two components because the eigenvalues drop significantly after the second component and then level out beyond this point. This satisfies the Kaiser criterion, which states that eigenvalues must be greater than one, and backs up a two-component solution. Based on the scree plot, it is possible to recommend the extraction of two principal components because after the second component, the eigenvalues decrease significantly, and adding additional components would not result in a significant increase in the explained variability.

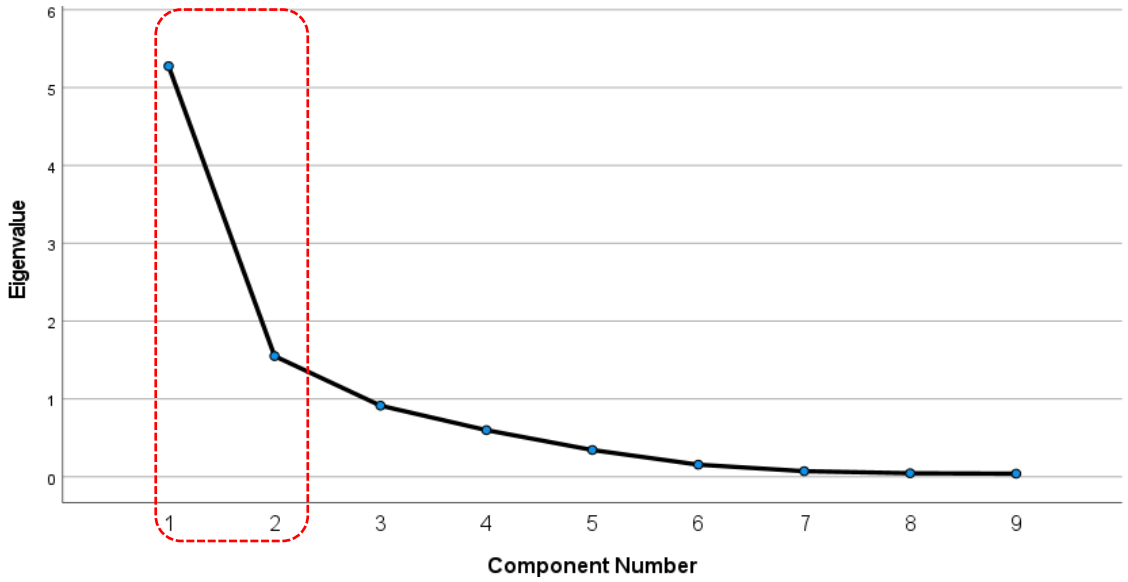

Figure 1. Scree plot of components number
Source: own processing in SPSS

The table 4 presents the factor loadings of various sustainability-related variables on two principal components (Component 1 and Component 2). These values indicate the degree to which each variable is associated with the respective component. It is evident that there is a major difference between two approaches to sustainability. It is important to note that circular economy techniques, which include trash reduction, recycling, and sustainable design, are distinct from resource efficiency, which involves conserving water and energy. In the context of sustainability programs, it is possible that businesses that prioritize water and energy saving would not necessarily place an emphasis on circularity, and vice versa. This suggests that various strategic interests are involved.

Table 4

Rotated Factor Loadings of Variables from PCA

Variable	Component 1	Component 2
Saving water (%)	-	0.888
Saving energy (%)	-	0.795
Renewable energy (%)	0.654	-
Saving materials (%)	0.760	-
Green suppliers (%)	0.790	-
Minimising waste (%)	0.926	-
Selling residues and waste (%)	0.894	-
Recycling (%)	0.820	-
Designing products (%)	0.876	-

Source: own processing in SPSS

For these purposes, it is appropriate to proceed with two main components. The final step of PCA is a graphical representation in the form of a biplot (Figure 2), which visually illustrates how variables correlate

with the principal components. In this biplot, the red vectors indicate the correlation of variables with the extracted principal components (PC1 and PC2).

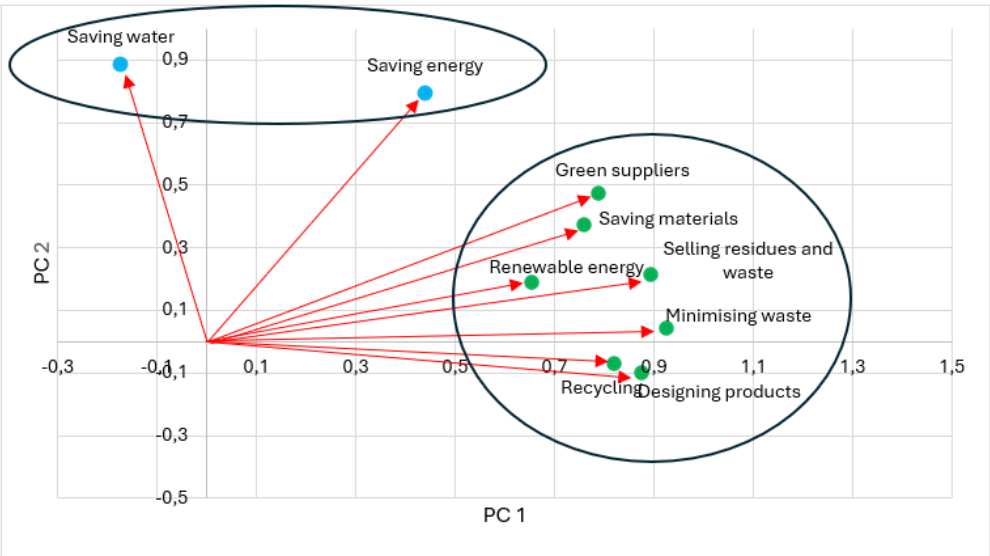

Figure 2. Biplot of components
Source: own processing in SPSS

Group 1: Resource Efficiency (PC2 Orientation). The first group of variables, including saving water and saving energy, is primarily oriented along the PC2 axis. This suggests that PC2 mainly captures activities aimed at resource efficiency, particularly in water and energy conservation. These activities are commonly found in manufacturing sectors and businesses focusing on environmental resource efficiency. Moreover, the smallest angle between these variables implies a strong correlation, indicating that companies implementing measures to save water are also likely to invest in saving energy, creating a synergistic effect. This supports the idea that businesses integrating resource efficiency strategies tend to approach both water and energy conservation as part of a unified sustainability effort.

Group 2: Circular Economy and Waste Management (PC1 Orientation). The second group of variables, oriented more towards the PC1 axis, includes: Green suppliers; Saving materials; Renewable energy; Selling residues and waste to other companies; Minimizing waste; Recycling; Designing products. This indicates a broad spectrum of activities related to circular economy principles, such as waste management, recycling, and sustainable product design. These activities emphasize repeated resource use and the integration of sustainability principles from the early stages of production. A key insight from the analysis is that measures for saving water tend to have negative values on PC1, while designing products has positive values on PC1. This indicates that companies prioritizing water conservation are less likely to invest in product design that promotes circularity and reuse.

Contrasting Strategies: Water Conservation vs. Product Design. The largest angle between variables is observed between saving water and designing products, indicating a negative correlation. It means that businesses focusing on water conservation place the *least* emphasis on sustainable product design. Conversely, companies that integrate circular economy principles into product design and manufacturing also tend to focus on subsequent recycling and reuse strategies.

The PCA biplot effectively reveals two dominant sustainability strategies among businesses. Resource Efficiency Strategy (PC2): Prioritizing water and energy savings, commonly found in manufacturing

industries. Circular Economy Strategy (PC1): Focusing on waste reduction, recycling, and sustainable product design, typically seen in industries embracing circular economy principles. The negative correlation between water conservation and product design further emphasizes that companies specializing in saving water often do not prioritize circular product design, whereas those investing in circular product development also focus on recycling and waste management. This analysis provides valuable insights into how businesses align their sustainability strategies, either towards resource efficiency or circular economy principles, and how these strategies may sometimes be in contrast with each other.

Specifically, the study also focuses on how the size of the company affects the implementation of circular economy measures. Figure 3 indicates a heat map showing this development. It can be declared that the larger the number of employees a company has, the more ecological and environmental measures can be practically implemented (with the exception of water saving measures in the production process).Most companies are actively optimizing their energy sources for economy and efficiency. The search for renewable energy sources reaches lower percentages, but according to the survey, more and more companies are considering new energy options. According to the research, up to 93 % SMEs implement at least one circular economy activity (European Commision, 2024).

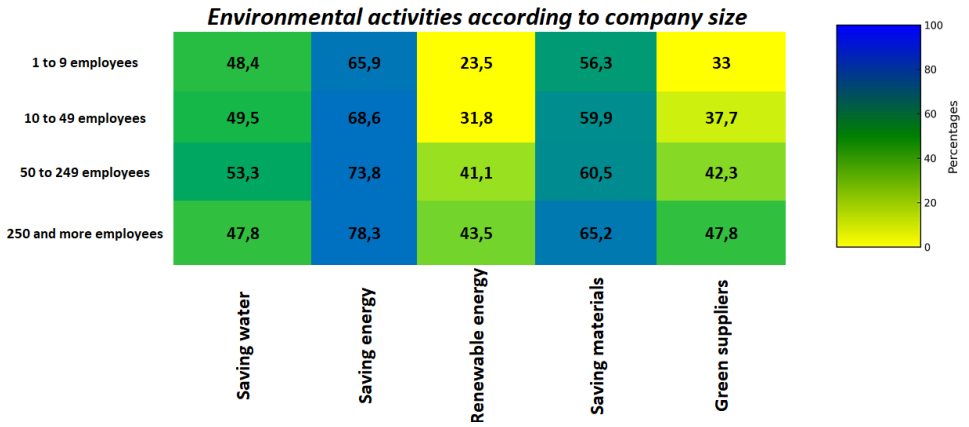

Figure 3. Selected ecological measures and their percentage representation in surveyed companies
Source: own processing according to European Commision (2024)

The circular economy's principles, including reuse, recycling, and regeneration, are proposed as the foundation for the creation of innovative solutions that establish a socioeconomic model that separates growth from resource consumption, thereby ensuring a consistent supply, stabilizing markets, and reducing reliance on finite raw materials. It is the goal of the implementation of circular economy principles to improve resource efficiency as a means of addressing the depletion and degradation of resources, as well as the mounting vulnerabilities that are occurring.

The study identifies two primary strategies for SMEs in the EU using the circular economy. Companies who follow these policies usually doing so cooperatively. The first strategy emphasizes resource efficiency, especially water and energy economy. The second method is focused on circular solutions that support the consistent use of materials: waste reduction, recycling, and environmentally responsible product design. Remarkably, up to 93% of SMEs engage in at least one circular economy initiative. Finally, the research offers important consequences for managers and legislators to enable synergies between many sustainability strategies and better control the EU's change towards a circular economy.

The notion of sustainable firm performance has garnered considerable attention in the very competitive corporate landscape. Industries have significantly increased the adoption and implementation of circular

economy methods. Implementing a recognized approach to circular economy principles may accelerate a company's achievement of sustainable business performance (Amin et al., 2024). Despite the apparent contradiction between ethical corporate activity and profit maximisation, multiple studies have shown that ethical conduct is essential for a company's long-term viability (Zvarikova et al., 2024). The study by Mor & Ravindra (2023) determined that waste-to-energy technologies necessitate sufficient financial and government support. Furthermore, the operation of waste-to-energy facilities and the construction of engineered landfills must be integrated to ensure a secure waste disposal system. These findings indirectly support this study, as waste management is becoming an important part of corporate activities, without which it is impossible to consider waste as a resource.

It is anticipated that the closing of the loops of economic systems will contribute to a reduction in the amount of pollution that is released into the environment, a reduction in the amount of natural resources that are used, and a reduction in the amount of capital and energy that is required for the processes of winning and processing recycled material (Seroka-Stolka & Ociepa-Kubicka, 2019). In addition, business owners started placing a higher emphasis on environmental concerns, which included everything from the protection of the environment, the production of environmentally friendly products, and the implementation of strong ethical values in business decisions. This resulted in the development of a new viewpoint on the profitability of businesses, which is now known as firm performance in a setting driven by sustainability, where social and environmental values are very important (Soto-Acosta et al., 2016). The European Union member states are clearly advancing their eco-innovation initiatives based on national norms; nonetheless, the need for harmonizing sustainability principles is becoming imperative (Juracka et al., 2024; Triguero et al., 2022).

The findings of this study support the idea that larger businesses are more willing to invest in more comprehensive circular economy strategies, suggesting the importance of EU policy instruments, as reported by De Pascale et al. (2023). In addition, they demonstrate that the transition to circularity and the next generation of sustainable, human-centered, and resilient Industry 5.0 cannot occur on their own in the economic sectors of the European Union (Mesjasz-Lech et al., 2024; Jawor & Matviienko, 2023). This also indirectly supports the findings of this study that the transition to a circular economy cannot take place in isolation in individual EU economic sectors.

According to García-Quevedo et al. (2020), the majority of SMEs see regulation, characterized by complex administrative or legal processes and the expenses associated with compliance, as the primary impediment to engaging in circular economy activities. Conversely, a limited number of firms cite the deficiency of human resources. The findings of Maman et al. (2024) study indicate that certain aspects of businesses might provide an explanation for the likelihood of implementing environmentally conscious activities. The size of small and medium-sized enterprises (SMEs) is vital for all kinds of eco-initiatives; more specifically, it is a highly essential component for the development of management that is focused on sustainability. When it comes to all kinds of projects, bigger small and medium-sized enterprises (SMEs) are more likely to implement sustainable management. These businesses are often distinguished by a better availability of resources and a management vision that is focused on the future. Moreover, according to the study by Doukas et al. (2012), it is widely acknowledged that the localization of global concerns, such as the sustainability of energy, is a subject of universal concern and of the utmost significance. The findings by Constantin et al. (2021) indicate that there is a significant disparity in the sustainability of the businesses that have been reported, and it is advised that the majority of these businesses take steps to enhance their respective sustainability performance ratings. Furthermore, Tutak & Brodny (2024) make it abundantly evident that there is a positive association between the growth of circular economies at the national level and the socio-economic development of the country. However, the progress made in the circular economy does not have an immediate influence on the environmental sustainability of the countries.

The building of the composite measure that encompasses a variety of features of circular economy requires the use of a methodology that is based on the combination of PCA and PROMETHEE (Stanković et al., 2021). The degree of development of a country's circular economy is assessed based on eleven indicators of the circular economy, which are organized into the following categories: production and consumption, waste management, secondary raw resources, and competitiveness and innovation throughout the length of time. Although the situation differs significantly across nations, a study by Bassi & Dias (2019) revealed that 73.2% of the enterprises had completed or were in the midst of completing at least one circular economy activity in the previous three years. The following factors influence green behavior at the company level: size, total turnover, R&D %, and activity type. The circular economy practice that SMEs use the most is minimizing waste through recycling, reusing, or selling waste to another business (55.4% of firms have adopted or are about to adopt this policy). This is followed by redesigning products and services to use less material or to use recycled material (34.4%), and re-planning energy usage to minimize consumption (37.7% of SMEs). The paper's findings reveal a strong link between green occupations, environmental skills, and the adoption of circular-economy practices. These findings clearly confirm the results of this study, and they also remind us that the horizon of adopting circular activities is relatively new and their implementation has taken place mainly in recent years, when interest in circularity has increased. Furthermore, the findings indicate an interaction impact with other business characteristics, such as age, size, turnover, and economic-activity sector (Bassi & Guidolin, 2021). These findings highlight the need for strategies for different types of businesses in supporting the circular economy, where different factors at the business level play a key role, and are practically in line with the results of this study.

Recycling is a significant component of the EU's circular economy indicators and appropriate waste management is a vital part of maintaining resource efficiency and sustainable economic growth in Europe (Mazur-Wierzbicka, 2021). The research by also reveals another important result on the identification of the circular economy themes - recycling, waste management and material circularity - that have been well-developed by EU nations and those which countries should focus more on in the development of the circular economy, including renewable energy, environmental technologies and themes linked with emissions and residues (de Oliveira Frascareli et al., 2024). These studies thus support our findings and their interconnections and interactions.

Levicky et al. (2021) conducted a study that evaluated the implementation of circular economy principles in 169 micro-enterprises in Slovakia. These identify the size of the company as a key factor influencing the implementation of circular economy measures. This may include simple measures to reduce waste or improve efficiency, which is consistent with our findings that companies often implement resource efficiency activities or circular strategies. The results of the study John et al. (2023) revealed that over 26% of SMEs do not incorporate any form of circular economy principles into their business processes. Nevertheless, more than 46% of medium-sized enterprises engage in three to five activities that are fundamental and require minimal or no cost to implement, which are associated with a circular economy. Compared to the conducted study, it shows that medium-sized enterprises often engage in three to five basic circular economy activities that require minimal or no costs.

5. CONCLUSION

The European Union has recognised the importance of the circular economy as a development priority and has integrated it into its industrial strategy. The transition to a sustainable, low-carbon, resource-efficient, and competitive economy is essential to achieving the EU's long-term environmental and economic goals. This shift represents a crucial step toward reducing resource dependency, minimizing environmental impact, and enhancing industrial resilience. The study provides practical implications for

implementing circular economy principles at the national level across EU countries. Findings from the survey indicate that an increasing number of enterprises are interested in adopting circular economy initiatives. The PCA results offer valuable insights for policymakers and businesses, helping them identify key areas for progress. Graphical and quantitative representations from the analysis clearly demonstrate that companies implement circular activities in two fundamental directions. The first direction is resource efficiency, particularly saving water and energy, which are highly interconnected. The study confirms that companies implementing water-saving measures in production are also likely to develop and apply processes aimed at reducing energy consumption. This group is dominant in manufacturing sectors or in the companies that focus primarily on the efficient use of environmental resources. The second dimension emphasizes circularity, which involves reusing materials and resources from the early stages of the production process. This includes activities such as waste management, recycling, and sustainable product design. The findings reveal that companies prioritizing resource efficiency do not integrate circularity principles as extensively as in their production processes. This suggests that they place less emphasis on product reuse, recycling, renovation, or remanufacturing.

This research experimentally compares resource efficiency and circular operations in SMEs, adding to circular economy understanding. PCA shows that SMEs prefer resource-saving strategies (water and energy conservation) or circular strategies (recycling, waste minimization, and eco-design of products), but rarely both. These findings enhance the theoretical conversation on SMEs' transition to sustainable business by showing that the circular economy is a combination of varied, often contradicting methods. The research adds to strategic management and eco-innovation literature by emphasizing the role of firm size and industry in implementing sustainable strategies. The results indicate that bigger organizations are more ready to spend in complicated circular initiatives, whereas smaller companies choose low-cost and simpler operations. These results expand corporate environmental strategy theory and may help SMEs create sustainable business strategies.

The results show that companies that implement water saving measures rarely invest in product design that supports recycling and reuse of materials. The recommendation for managers is therefore to review the strategy and strive to integrate both approaches. Larger SMEs are more willing to invest in more comprehensive circular economy strategies, using greater resources for research and development. This suggests the need to build knowledge and cooperation networks between companies of different sizes, where smaller companies could benefit from the know-how of larger entities. The study confirms that companies focus on low-cost circular economy activities (e recycling and waste minimization). However, managers should also consider investing in eco-design and innovative solutions that can bring longer-term competitiveness and resilience to market challenges.

Future challenges in this research can be explored on multiple levels, including economic, technological, and environmental feasibility. The evaluation of circular economy strategies should always consider their practicability across these three dimensions. Additional factors such as the anticipated timeframe, stakeholder support, scaling potential, and societal impact could further supplement the analysis. It is also essential to examine potential obstacles categorized by economic factors, market behavior, legislation, and social considerations. The study acknowledges certain limitations that must be addressed in future research. Circular economy research and environmental innovation extend beyond purely ecological aspects, and future studies should incorporate broader indicators such as the Eco-Innovation Index of European Union countries. This index reflects not only environmental impacts but also the social and economic effects of adopting eco-friendly innovations. Similarly, the European Innovation Scoreboard could provide further insights into national and regional innovation performance. One notable limitation of this study is its methodological approach, which evaluates the sample as a whole rather than analyzing specific national or regional differences within the EU. The absence of detailed country-specific reflections

limits the depth of the findings and suggests a need for further investigation. Each method of modeling circularity has distinct advantages and disadvantages, and future research should explore these approaches to enhance the understanding and application of circular economy strategies.

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