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Measuring Circularity and Sustainability in Southern Europe: A Comparative Empirical Analysis of Portugal, Spain, Italy, and Greece

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Abstract

This study empirically examines the relationship between economic circularity and environmental performance in four Southern European countries: Portugal, Spain, Italy, and Greece. Using secondary data from Eurostat (2014–2022), it investigates three core hypotheses: (i) the association between the Circular Material Use Rate (CMUR) and per capita CO₂ emissions; (ii) the impact of public environmental expenditure on circular performance; and (iii) differences in circularity across countries. The results confirm a negative and statistically significant relationship between CMUR and CO₂ emissions, as well as a positive association between public expenditure on environmental protection (PEEP) and circularity levels. Contrary to the initial assumption, Italy and Greece exhibited higher average circularity rates than Portugal and Spain. These findings underscore the relevance of the circular economy as a climate mitigation tool and highlight the critical role of public policy in fostering sustainable practices. Furthermore, they challenge the notion of regional homogeneity, emphasising the need for tailored national strategies that reflect institutional and economic specificities. The study's limitations – particularly the restricted sample size and absence of longitudinal analysis – suggest avenues for future research aimed at deepening the understanding of structural and policy-related dynamics that shape circular economy implementation across the European Union (EU).

Keywords: Circular Economy, Co₂ Emissions, Environmental Policy, Southern Europe, Public Environmental Expenditure.

Introduction

Growing environmental degradation, the depletion of natural resources and the challenges posed by climate change have driven the transition from linear economic models to more sustainable approaches centred on the principles of the circular economy (CE). The European Union (EU) has led this movement with ambitious policies such as the Green Deal (Sandri et al., 2025) and the Circular Economy Action Plan (Reins & Wijns, 2025), encouraging member states to adopt practices that promote reuse, recycling and resource efficiency. However, the implementation and results of these practices vary substantially between countries, especially those in southern Europe.

In this context, indicators such as the Circular Material Use Rate (CMUR) and the Green Innovation Index have emerged as central tools for measuring countries' progress towards a circular economy. At the same time, environmental impacts, particularly CO₂ emissions per capita, remain a critical criterion for evaluating sustainability policies. Understanding the interplay between circularity, innovation, and environmental performance is essential for evaluating the effectiveness of the strategies adopted by southern European countries (notably

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Portugal, Spain, Italy and Greece) whose economic, structural and environmental trajectory shows historical similarities, but also significant contrasts.

Despite the growing body of literature on the CE in the EU, there is still a significant empirical gap in terms of quantitative comparisons between southern European countries, considering multiple indicators of circularity. In addition, there is a lack of analyses that empirically test causal relationships between the circular use of materials and CO₂ emissions, as well as the role of ecological innovation in national circular performance. It is hoped that this will contribute to the formulation of more effective public policies, offering empirical support that will enable the EU to strengthen its regional cohesion in terms of sustainable development. The analysis is relevant not only to researchers and policymakers, but also for productive and social sectors interested in understanding the determinants and impacts of circularity strategies in the European Mediterranean context.

Literature Review and Theoretical Framework

Relationship between the Circular Material Use Index and CO₂ emissions

Several studies strongly support the hypothesis that an increase in CMUR is associated with a reduction in CO₂ emissions per capita. Sardanou et al. (2023) pointed out that a 1% increase in recyclable waste leads to a 0.5% drop in CO₂ emissions. This pattern of negative correlation is consistently supported in the literature, with studies indicating that improvements in circularity metrics are linked to enhanced environmental performance (Arion et al. 2023; Hailemariam & Erdiaw-Kwasie, 2022; Pao & Chen, 2021).

Balsalobre-Lorente et al. (2021, 2022) reinforce these findings by applying the Environmental Kuznets Curve (EKC) model to southern European countries (PIIGS), demonstrating that economic growth combined with increased circularity can reduce emissions. In addition, Alola et al. (2025) used quantile regressions to show that the effects of reusing materials on emissions vary according to the country profile but generally point to mitigating impacts. Thus, there is consolidated evidence that CMUR is an inverse predictor of CO₂ emissions, supporting the formulation of the following hypothesis:

Hypothesis 1: The higher the circular use of materials index, the lower the per capita CO₂ emissions.

Ecological Innovation and Circularity Performance

The literature is also robust in connecting green innovation, public investment and circularity performance. García-Valderrama et al. (2024) identified a direct association between recycling efficiency, innovation and CE implementation. Platon et al. (2023) revealed that eco-innovation is key to reducing the per capita material footprint. In addition, Khan and Idrees (2024) showed that eco-innovation dimensions reduce greenhouse gas emissions, while Hysa et al. (2020) highlighted that recycling-related patents and private investments positively impact economic growth and CE performance.

The influence of public spending and R&D investment has been highlighted in various studies (Leitão et al., 2022; Škrinjarić, 2020; Tançau et al., 2018; Trica et al., 2019), where it is found that countries with greater investment in environmental innovation have superior circular performance. According to the above, strong evidence is established to support that green innovation is a driver for the advancement of CE:

Hypothesis 2: Higher PSEO is positively associated with the circularity index (measured by CMUR).

Comparisons between Southern European countries

Although many of the studies included in this review include data from Portugal, Spain, Italy and Greece, few provide direct comparisons of CE performance between these specific countries. However, some studies offer information on the relative performance of Southern European countries in general or provide data from individual countries that can be used for comparison.

Castillo-Díaz et al. (2024) found that Italy was among the best performing countries in CE practices, following Germany and France. This suggests that Italy may be outperforming other southern European countries in some aspects of CE implementation. D'Adamo et al. (2024) also identified Italy as one of the leading countries in CE performance, along with Belgium and the Netherlands. This further supports Italy's strong position in relation to other southern European nations. However, Giannakitsidou et al. (2020) reported that Spain and France perform worse than some Eastern European countries, such as Slovenia and Poland, in terms of municipal solid waste management and recycling rates. This indicates that Spain may be falling behind in certain CE indicators.

Hondroyiannis et al. (2024) found that Southern European countries generally have lower circularity rates than their Northern European counterparts. This suggests that, as a group, Southern European countries (including Portugal, Spain, Italy and Greece) may be underperforming in terms of CE implementation. Skare et al. (2024) identified Portugal as among the worst performers in terms of the rate of use of circular materials and the ratio of public transport, while Škrinjarić (2020) listed Greece among the worst performers in terms of several economic and social indicators related to CE performance.

These findings present a mixed picture of the relative performance of Portugal, Spain, Italy and Greece on CE indicators. Italy seems to be performing relatively well, often ranking among the top EU countries in CE implementation. On the other hand, Spain has a mixed performance, with some studies indicating lower performance in specific areas such as waste management. Finally, Portugal and Greece are often mentioned among the worst performing countries in various CE indicators.

The studies analysed do not provide strong evidence to support the hypothesis that Portugal and Spain significantly outperform Greece and Italy in integrated circularity indicators. In fact, some studies suggest that Italy may be outperforming other Southern European countries, including Spain and Portugal. However, the lack of direct and consistent comparisons between these specific countries in the studies analysed makes it difficult to draw definitive conclusions, leading to the definition of the following hypothesis:

Hypothesis 3: Portugal and Spain will have significantly higher circularity rates than Italy and Greece.

Academic Contribution

Once the review has been carried out and the hypotheses that will be studied have been established, the expected contribution of the study to the existing academic literature can be defined (Table 1).

Hypotheses	Evidence	Highlights
H1: The higher the circular use of materials index, the lower the per capita CO ₂ emissions	Strong empirical support	Sardianou et al. (2023) Hailemariam & Erdiaw-Kwasie (2023) Balsalobre-Lorente et al. (2021)
H2: Higher PSEO is positively associated with the circularity index (measured by CMUR)	Solid theoretical and empirical basis	Platon et al. (2023) Khan & Idrees (2024) Trica et al. (2019)
H3: Portugal and Spain will have significantly higher circularity rates than Italy and Greece	Weak and contradictory support	Italy often superior, Portugal among the worst

Table 1: Integration of Hypotheses in Scientific Literature

Source: Author's own work

Methodology

This study aims to empirically investigate the relationship between economic circularity and environmental performance in southern European countries (Portugal, Spain, Italy and Greece), focusing on three main hypotheses.

As illustrated in Figure 1, the relationships between the variables under consideration and the hypotheses that form the foundation of the research model are depicted.

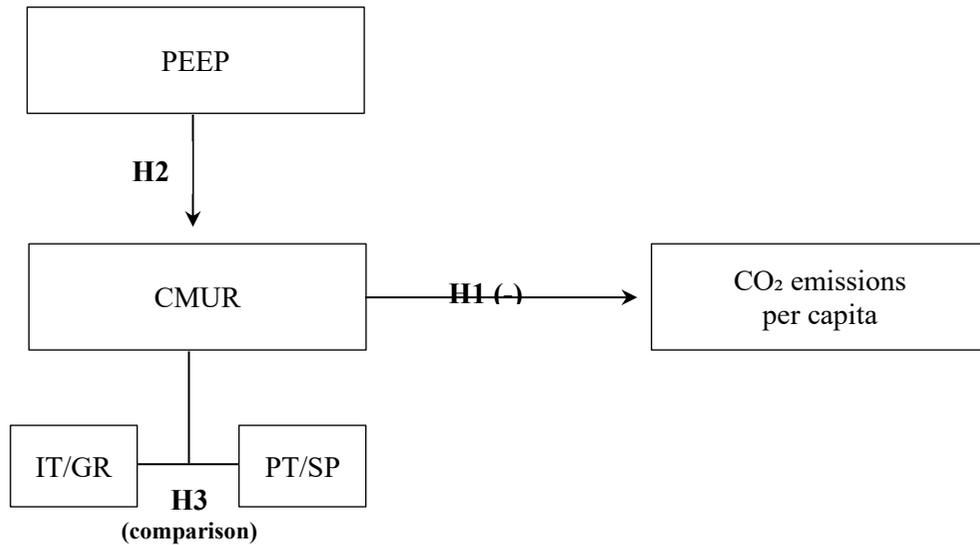


Figure 1: Conceptual Model: Circularity and Sustainability in Southern European Countries

Note: PEEP= Public expenditure on environmental protection; CMUR = Circular Material Use Rate

Source: Author’s own work

The choice of data and indicators reflects both the theoretical relevance of the concepts of CE and climate sustainability, and the availability and statistical comparability between EU countries. The data used was taken from Eurostat (2025), the European Union’s main source of statistics, recognised for its standardised methodology, consistent temporal coverage and institutional validation. This guarantees international comparability and methodological consistency, which are essential for comparative analyses.

The present study adopts a quantitative and comparative approach to analyse the relationship between economic circularity and environmental performance in four southern European countries.

Contextualisation of the Sample

The sample consists of Portugal, Spain, Italy and Greece. The selection was based on criteria of theoretical and contextual relevance, as these countries share economic, political and environmental characteristics that distinguish them from other regions of the European Union. These are economies characterised by moderate levels of industrialisation, structural vulnerabilities in the environmental field and a shared trajectory of European integration, particularly regarding sustainability and circular innovation policies (Torres-Rodríguez et al., 2020).

The utilisation of official secondary data from Eurostat (2025) for the most recent period available ensures methodological comparability between countries. However, it should be noted

that the study's small sample size constitutes an inherent limitation, preventing the establishment of more robust statistical generalisations. However, the focus on these four cases is justified given the exploratory and comparative nature of the research, which seeks to understand the dynamics of circularity and sustainability in a European sub-region with common challenges (Silva & Pereira, 2021).

Data Collection Process

In this article, it was elected to utilise secondary data from Eurostat (2025), recognised as the official repository of EU statistics. The selection of this database is substantiated by its methodological consistency, the reliability of the indicators reported, and its comprehensive coverage of Member States, between 2014 and 2022, period for which data is available.

The selection of variables was guided by their relevance to the study of sustainability and the circular economy, allowing for a structured comparative analysis between the countries in focus. Therefore, three primary indicators were taken into consideration and operationalised in the following manner: The CMUR, expressed as a percentage, is a measure of the proportion of reused materials in a country's total material consumption. Per capita CO₂ emissions, measured in tonnes per inhabitant, are an indicator of the intensity of carbon emissions associated with national consumption and production. PSEO, calculated as a percentage of GDP, is an indicator of governments' financial commitment to sustainability and environmental preservation policies. The selection of these indicators was informed by their theoretical pertinence to the concepts of circularity and sustainability.

Statistical Procedures

Following the identification and selection of the relevant indicators for each of the hypotheses formulated, the data were systematised in a comparative matrix. From this, analytical variables were constructed that aligned with the conceptual model of the study. The statistical analyses were conducted using IBM SPSS Statistics software, version 29.

Results

Prior to the presentation of the regression models, Pearson's bivariate correlations between the primary variables were calculated to identifying preliminary associations and evaluating the potential risks of collinearity.

The results (Table 2) demonstrate that the correlations range from weak to moderate in magnitude. The only statistically significant correlation observed was between the CMUR and PEEP, suggesting a possible convergence between political efforts and circular practices. However, notably the small sample size ($n = 9$) limits the statistical robustness of these correlations.

	1	2
1. CO ₂ emissions per capita	-	
2. CMUR	- 0.320	-
3. PEEP	- 0.640	0.727*

Table 2: Pearson Correlation Coefficients between the Variables in the Model

Note: CMUR = Circular material use rate; PEEP = Public expenditure on environmental protection; * $p < 0.05$; Source: Author's own work

To test the hypotheses formulated and assess the explanatory contribution of the different indicators to the variability of per capita CO₂ emissions (DV), multiple linear regression models were estimated. This statistical approach enables the assessment of the simultaneous effect of independent variables (IVs), namely the CMUR and PEEP, on the dependent variable, whilst controlling the individual contribution of each predictor in the context of the overall model. It is imperative to exercise caution when interpreting the results, given the modest sample size. Nevertheless, this analysis enabled the assessment of relevant trends and the identification of potential causal relationships between the variables under study.

The findings of the linear regression analysis indicate a negative and statistically significant relationship between CMUR and per capita CO₂ emissions ($R^2 = 0.611$; $p < 0.05$). The model is linear and it revealed that 61.1% of the variability in CO₂ emissions is significantly explained by CMUR. The standardised coefficient (Beta = - 0.782) confirms the negative direction of the relationship, while the unstandardised coefficient indicates that variations in CMUR are associated with minimal but statistically significant residual changes in per capita CO₂ emissions ($t = -3.545$; $p < 0.05$). The findings of this study lend support to **Hypothesis 1**, providing empirical evidence that greater circularity is associated with a reduced carbon footprint in the countries under analysis.

Furthermore, a positive and statistically significant relationship was identified between PEEP and CMUR ($R^2 = 0.528$; $p < 0.05$). The model demonstrates linearity ($F_{(1, 7)} = 7.840$; $p < 0.05$) and accounts for approximately 46.1% of the variability in the circularity index. The standardised coefficient (Beta = 0.727) indicates a robust positive association between the two indicators. Conversely, the unstandardised coefficient suggests that a one percentage point rise in GPPA is linked to an estimated increase of 0.041 points in CMUR ($t = 2.800$; $p < 0.05$). These results provide empirical validation of **Hypothesis 2**, emphasising the pivotal role of public investment in fostering practices aligned with the principles of the circular economy.

In the ensuing study, Hypothesis 3 sought to determine whether these dynamics are reflected in a distinct manner across the four southern European countries. The assumption underpinning this inquiry is that contexts characterised by enhanced institutional development and integration into EU environmental policies, exemplified by Portugal and Spain (Group 1), exhibit, on average, considerably higher circularity rates in comparison to those observed in Italy and Greece (Group 2). The findings indicate statistically significant variations in the mean CMUR rates of the two groups. The findings suggest that Group 2 ($M = 10.98$; $SD = 8.04$) exhibits higher mean values in comparison to Group 1 ($M = 5.51$; $SD = 3.25$). The difference between the two groups is statistically significant ($t = -2.675$; $p < 0.05$), with a 95% confidence interval between -9.71 and -1.23. In view of the above, it can be concluded that Italy and Greece perform better in terms of circularity index than Portugal and Spain, thereby refuting **Hypothesis 3**.

Discussion

In addition to testing the three hypotheses formulated, the statistical analysis provided empirically based data to understand the dynamics between CMUR, PEEP and per capita CO₂ emissions in the four southern European countries considered. The initial results pertain to Hypothesis 1, the validation of which is predicated on the identification of a negative and statistically significant relationship between CMUR and per capita CO₂ emissions. This corroborates the negative correlation previously documented by Pao and Chen (2021). In the context of the PIIGS countries, Balsalobre-Lorente et al. (2021) demonstrated that enhancing circularity is associated with a transition to less polluting production models, a phenomenon that

aligns with the predictions of the EKC. Recent studies, including those by Hailemariam and Erdiaw-Kwasie (2022) and Arion et al. (2023), have indicated that enhancing circular indicators is correlated with enhanced environmental performance. As asserted by Sardanou et al. (2023), the implementation of integrated circular policies has been demonstrated to contribute to the mitigation of carbon emissions. This finding serves to reinforce the notion that enhancing resource efficiency is directly associated with the promotion of environmental sustainability. The results obtained serve to reinforce the importance of the CE as a mechanism for climate transition, a matter of relevance in the European context.

The second hypothesis was also confirmed by empirical data, which demonstrated a positive association between PSEO and the circularity index. This outcome aligns with the findings of Trica et al. (2019), who underscore the pivotal role of government budgetary initiatives in environmental affairs as a crucial predictor of circular performance, particularly in medium-sized economies akin to those in southern Europe. Subsequently, Platon et al. (2023) identified public expenditure as a primary factor contributing to the decline in raw material consumption within the European Union. Concurrently, Khan and Idrees (2024) demonstrated that the adoption of eco-innovation strategies promoted by robust public policies exerts a direct effect on the improvement of circularity indicators. These findings underscore the critical role of strategic public investment in driving structural transformations in resource management.

In contrast to the prevailing expectations, Hypothesis 3 was refuted by the results, which indicate higher average circularity rates in Group 2 countries (Italy and Greece) compared to Group 1 (Portugal and Spain). The difference in circularity rates between these two groups was found to be statistically significant at the 0.05 level of significance. This finding aligns with the studies by Škrinjarić (2020), who identified Portugal's substandard performance in multiple CE indicators, and with the data presented by Castillo-Díaz et al. (2024), who designated Italy as a model for circular best practices, particularly regarding the integration of innovation and resource efficiency. Furthermore, D'Adamo et al. (2024) have positioned Italy as one of the EU countries demonstrating the most favourable performance in terms of circularity indicators, surpassing numerous northern and southern European economies. The findings indicate that the intra-regional heterogeneity present within the southern European context is more pronounced than was previously documented. This observation necessitates a critical reassessment of national strategies and their respective effectiveness.

Theoretical and Practical Contributions

This study makes a significant contribution to the existing body of research on the CE and environmental sustainability in Europe by offering a focused comparison of Southern European countries, which are frequently underrepresented in pan-European quantitative studies. The research employs a multidimensional approach, integrating official indicators relating to the CMUR, CO₂ emissions and the GPPA, thereby linking economic, environmental and political aspects.

The findings of the study provide empirical evidence that validates the theoretical assumption that enhancing circularity is a contributing factor to mitigating carbon emissions. This outcome corroborates the formulations of the EKC within the Mediterranean context. Furthermore, it emphasises the pivotal function of public expenditure on the environment in fostering circularity, underscoring the significance of fiscal policy as a means of catalysing the ecological transition. The present study introduces a critical perspective on intra-regional asymmetries in southern Europe, which contradicts homogeneous approaches that tend to treat this region as a cohesive

From a practical standpoint, the study underscores the necessity for policymakers, public administration technicians, and organisations involved in formulating and monitoring sustainability strategies to adopt more inclusive policies tailored to regional particularities. The confirmation that public investment is positively associated with circular performance indicates that it is necessary to strengthen budgets allocated to environmental protection and promote integrated public policies with monitoring and evaluation mechanisms.

Evidence that circularity reduces CO₂ emissions reinforces the value of resource reuse and efficiency policies such as climate mitigation tools, in line with the objectives of the European Green Deal. The data also reveals significant discrepancies between countries in the same region, which reinforces the need to adopt differentiated strategies tailored to the institutional and economic specificities of each country. This research also contributes to supporting the definition of more realistic national targets within the framework of action plans for the CE and serves as a reference for comparative assessment between Member States with similar structural conditions.

Limitations and Future Research

The study's findings, both theoretical and empirical, are noteworthy. However, it is imperative to acknowledge the study's limitations, which highlight opportunities for deeper future research.

The primary constraint of this study is the limited sample size, encompassing only four countries, which restricts the statistical generalisation of the findings. While the selection was theoretically justified based on the structural homogeneity of southern European countries, the scarcity of observations limits the explanatory power and inferential robustness of certain models. It is recommended that future studies consider expanding the number of cases analysed, to include countries with comparable characteristics. Such countries might include Cyprus, Malta, or some Eastern European countries with similar transition trajectories.

A further limitation pertains to the nature of the data employed, which is derived from aggregate macroeconomic indicators. This option precludes the analysis of more subtle social and institutional dynamics that may influence the implementation of circularity policies. It is recommended that subsequent research endeavours encompass qualitative methodologies, such as interviews with policymakers or a documentary analysis of national strategies, to capture contextual nuances that are obscured by statistical data.

Furthermore, the adopted model assumes linear and one-dimensional relationships between variables. Although this is methodologically appropriate in an exploratory approach, it could be further developed using more sophisticated multivariate techniques. The implementation of multiple regression models, regional cluster analysis, or structural equation models will facilitate a more robust analysis.

It is also important to note that this analysis does not take into account the temporal dimension. The incorporation of time series is imperative in order to assess the stability of relationships over time and to identify structural changes associated with public policies or exogenous shocks, such as the pandemic caused by the severe acute respiratory syndrome (SARS-CoV-2) virus or the recent energy crisis.

Furthermore, the development of interregional comparative models is imperative, as these models facilitate a comprehensive analysis of the performance of southern countries in

comparison to those in other regions of the European Union, including the Nordic countries and the Member States of Eastern Europe. This methodological approach facilitates the evaluation of the specificity of the observed patterns, as well as their generalisability.

Conclusions

The analysis focused on the empirical exploration of the interrelationships between economic circularity, PEEP, and environmental performance in southern European countries, using comparable data from Eurostat. The operationalisation of three hypotheses enabled the verification of a statistically significant and negative association between the CMUR and per capita CO₂ emissions, thus confirming the relevance of the CE as an environmental mitigation strategy.

Concurrently, the findings indicated a favourable correlation between PEEP and levels of circularity, underscoring the pivotal function of public policies in catalysing the transition to more sustainable economic models. The comparison between the two groups of countries revealed that, contrary to the initial hypothesis, Italy and Greece have, on average, higher circularity rates than Portugal and Spain. These results call into question approaches based on the assumption of regional homogeneity and highlight the need to implement differentiated national strategies tailored to the specificities of each context.

The study emphasises the significance of incorporating integrated and empirically grounded approaches in the evaluation of sustainability policies. The identified limitations, namely the sample size and the absence of a longitudinal analysis, pave the way for further exploration of the structural and institutional dynamics that condition the implementation of the CE in the European Union. Achieving European sustainability requires tailored strategies that reflect the diverse realities of its regions, rather than a one-size-fits-all approach.

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