How are regions using European funds to promote the circular economy? Shedding light on factors explaining the pathway

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Abstract

Purpose – This study aims to examine the geographical spread of the EU-funded circular economy projects in the European Union.

Design/methodology/approach – The authors use a novel database of research and development projects funded by the European Regional Development Fund related to the circular economy to estimate a fractional response model on data for 231 European regions.

Findings – First, the authors detect a geographical pattern in the share of circular economy funds. Second, the authors find that institutional quality, employment, human capital and income may drive the concentration of circular economy research and development funds. Third, the authors find overall differences between technology projects and circular economy projects, suggesting that addressing the circular economy at the subnational level is complex.

JEL classification – C25, Q50, R11

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Social implications – This work can be helpful to disseminate Sustainable Development Goals (SDGs). In particular, the authors pay special emphasis on SDGs numbers 11 (Sustainable Cities and Communities) and 13 (Climate Action).

Originality/value – The findings confirm the existence of a geographical spread of the circular economy, which may be useful to move toward regional sustainable development in the European Union.

Keywords Circular economy, Regional funding absorption, European Union

Paper type Research paper

1. Introduction

A proper understanding of structural changes derived from modern economic growth requires two crucial issues to be addressed. It is fundamental to introduce regions into this discussion since the interregional distribution of income has been reducing over time (e.g. Sala-i-Martin, 1996) and, more importantly, an uneven distribution of economic activity has exacerbated regional disparities (Krugman, 1991). The dominant paradigm has been strictly linear, with products thrown away once they are used. This linear paradigm leaves no room to address crucial issues, such as assessing environmental damage or the recycling of resources. Consequently, critical voices have increasingly called for a transition to a new paradigm of sustainable development (e.g. Sachs, 2015). Extending product life cycles by reusing and recycling, as proposed by the circular economy (CE), can be considered an effective solution. An analysis of the geographical spread of the CE could shed light on these issues and contribute to empirical research.

The European Union (EU) can be considered as the ideal scope of analysis to examine the CE from a regional perspective, given the growing number of targets aimed at reducing pollution by raising environmental policy stringency. In the context of growing environmental policy initiatives, such as the European Green Deal, 26% of the total budget of the Structural and Investment Funds was targeted toward climate action objectives during the 2014–2020 programing period, among which CE actions were included (European Commission, 2023). However, the specific regional research and development (R&D) funding amounts targeted at developing CE actions remain, to the best of our knowledge, largely unexplored due to data paucity problems. Improved availability of data on such funding actions could yield a more comprehensive and profound understanding of the existing geographical spread of the CE.

Academic literature devoted to understanding the geographical spread of the CE is quite sprawling and countervailing. While it is mainly focused on the country level, overlooking the spatiality of the CE, most efforts have been oriented toward proposing EU CE indicators, mainly at the country level (Smol *et al.*, 2017). However, it has been argued that sharp regional CE differences exist, such as the regional divide found by Silvestri *et al.* (2020) in an analysis of different CE indicators. Niang *et al.* (2023) addressed the geographical spread of CE, but they restricted their analysis to the French local level and how CE could contribute to local job creation. Evidence also shows existing speed differences of cohesion funds absorption between EU regions, but this issue has been addressed from an overall perspective without disaggregating by the purpose of the funds (Santos *et al.*, 2024).

In our analysis, we aim to contribute to the existing literature by addressing the geographical spread of the CE in different ways. First, we provide a comprehensive overview of CE R&D projects to enable a better understanding of such projects, which Korhonen *et al.* (2018) highlighted as important in the short term. We enrich this discussion by comparing such projects with non-R&D technology projects and CE projects overall. Second, we provide a more in-depth description of how to measure the CE by identifying the amount of regional funding devoted to CE projects as a proportion of the total amount of regional funding in Europe. Third, we examine which factors may drive the allocation of CE regional R&D funding to European regions, which can be considered crucial to address the regional convergence issue in terms of CE regional adoption, as defined by Silvestri *et al.* (2020). Finally, in line with Niang *et al.*'s (2023) analysis, we examine the spatiality of CE by testing whether the CE performance in a region depends on the CE performance exhibited by neighboring regions.

To accomplish our research goals, we used a novel and unique database on the European Regional Development Fund (ERDF) beneficiary projects. This database collects the average funding during 2014–2020 (Bachtrögler *et al.*, 2021). Using text-mining techniques, we identified all the ERDF-funded projects in the CE field, disaggregated by geographical location. Using a fractional binary regression for the year 2014, we regressed the percentage of funds related to the CE over potential factors suggested by the academic literature. Our results confirm the existence of a geographical dimension associated with the CE and show which factors drive such regional patterns. Certain variables, such as regional quality of government, human capital, employment and income, may play a key role in explaining the allocation of CE funds because they are positively and negatively associated with this allocation and could facilitate convergence. We also find sharp differences between overall CE funds, technology CE funds and R&D CE funds, suggesting the existence of a geographical spread of the CE.

The remainder of the paper is organized as follows. Section 2 sketches the theoretical framework and the literature review. Section 3 describes the data and the methodology and Section 4 presents and discusses the results. Finally, Section 5 concludes.

2. Untangling the geographical dimension of the circular economy

2.1 The geographical spread of the circular economy: a novel view through the absorption of funds

As a starting point, we acknowledge that the study of the CE needs to address certain major shortcomings. First, the CE is a complex adaptive system that continuously evolves over time (Korhonen *et al.*, 2018) and needs to be properly understood. Second, we find no universal definition of the CE. This is particularly challenging in undertaking empirical research because no universal conclusions can be extrapolated and it leaves no room to understand specific critical aspects, such as consumers or business models (Kirchherr *et al.*, 2017). As Rodríguez-Pose (2013) pointed out, the absence of a universal definition is similar to the problem of extrapolating the study of institutional quality to higher levels of territorial disaggregation.

The introduction of the geographical dimension in this analysis stems from the field of New Economic Geography, which has brought major policy implications because economic activity tends to be unevenly located across space (Krugman, 1991). We acknowledge that industry and population are concentrated in specific areas within a country, meaning that agglomeration forces need to be addressed in the context of sustainable development and cleaner production techniques. Consequently, issues related to geography and regions are crucial to understanding the CE concept. More importantly, it has been argued that public policies must be designed at lower territorial levels of public administrations, which may confer upon regional governments a key role in managing environmental policies contingent on the CE (Arauzo-Carod *et al.*, 2022). Externalities derived from the CE also deserve a proper policy analysis, as they are more salient at the regional level (Bourdin and Torre, 2020).

We consider the absorptive capacity of firms as a proxy for the CE at the regional level because such capacity contributes to enhance regional innovation performance that may improve the learning process for the CE and give rise to regional disparities (e.g. Miguélez and Moreno, 2015). To obtain a more comprehensive regional glimpse of absorptive capacity, we consider ERDF. The ERDF is one of the most important institutional arrangements in the EU that aims to reduce regional disparities; its budget is EUR 230bn for the 2014–2020 programing period [1]. However, recent research has shown the existence of substantial heterogeneity of funding between EU regions in terms of absorptive capacity. Marques-Santos *et al.* (2024) found sharp variations in territorial performance related to spending the allocated cohesion budget for the programing period 2014–2020, whereas prior studies have only focused on the total absorption of funds at the end of the period, leaving aside average performance. These studies also suggest that regional funding could capture decentralized governance efforts. This is coherent with the territorial dynamics of CE, which is highly influenced by the existence of more pronounced proximity relations when increasing territorial disaggregation (Bourdin and Torre, 2020). These prior considerations give rise to the research hypotheses *H1a* and *H1b*, which are defined as follows:

H1a. The regional CE performance can be proxied by the amount of regional funds devoted to CE.

H1b. The speed of absorption of regional funds related to the CE differs by region.

2.2 The geographical spread of the circular economy: understanding the differences

Despite the growing importance of the CE in addressing environmental and sustainability issues, prior studies circumvent the subnational dimension when addressing fund absorption. Data paucity can be considered as the main barrier to overcome to explain the geographical patterns of CE projects. This important gap in our knowledge can be filled by conducting novel research to obtain relevant data. Recently, Bachtrögler *et al.* (2021) developed a novel database of R&D projects co-funded by the ERDF.

Another important caveat arises in addressing the geographical spread of the CE by bringing the subnational dimension to the discussion. Several exceptions provide a general but, to the best of our knowledge, still limited understanding of the CE at the subnational level. Smol *et al.* (2017) provided benchmarks for potential indicators (e.g. employment) that could be used to provide a regional glimpse of the CE. Silvestri *et al.* (2020) developed a static and dynamic regional indicator by weighting socioeconomic and environmental dimensions contingent on the CE for European regions. Their findings suggest not only the existence of a sharp regional divide in terms of the CE in Europe but also that the least developed European regions in terms of their CE performance could exert substantial effort to reach the level of the most developed regions. Finally, Niang *et al.* (2023) studied job activities related to the CE and found a spatial pattern measured by the existence of spatial autocorrelation. However, they did not explore potential determinants of this spatial pattern and restricted their analysis to the local level in France. The issue of the geographical spreading of the CE should entail not only intraregional comparisons but also interregional ones since, according to Korhonen *et al.* (2018), regional interdependencies may be associated with the complexity of the CE activities. This comparison can only be achieved by incorporating a large number of regions from various EU countries.

At the firm level, Segarra-Blasco *et al.* (2024) recently identified explanatory factors for the three dimensions of CE – reduce, recycle and redesign – using three separate cross sections in 2015, 2018 and 2021. Their findings suggest the importance of certain institutional drivers measured by knowledge and environmental spillovers on CE practices. Although certain regional variations among European countries are considered, the territorial dimension is left aside from their discussion.

In this context, a baseline empirical framework to identify the main regional explanatory factors for CE is essential to deliver proper policy purposes. Regarding the absorption of funds, absorptive capacity is highly related to innovation (Zahra and George, 2002). This fact leads us to propose a theoretical framework contingent on explaining differences in innovation efforts at the regional level. We build on the well-known phenomena of the geography of innovation because innovation forces are more intense with higher levels of proximity (Capello and Lenzi, 2018) but, at the same time, we acknowledge that this framework is a complex phenomenon (Peiró-Palomino, 2019) that requires incorporating different dimensions in the discussion. The geography of innovation is rigorously rooted in the regional innovation systems paradigm (e.g. Iammarino, 2005), which assume that innovation is unequally distributed across regions due to the existence of sharp differences in socioeconomic and institutional endowments. We found different attempts in the prior literature to identify the potential explanatory factors regarding innovation at the subnational level (e.g. Crescenzi and Rodríguez-Pose, 2013; Peiró-Palomino, 2019; Rodríguez-Pose and Di Cataldo, 2015). In this regional context, two relevant issues arise. First, technology can be either defined in a narrow sense or can interact and evolve parallel to the systems of innovation (Hekkert *et al.*, 2007). It would thus be desirable to untangle technology and innovation for policy purposes. The second issue is spatiality because the CE performance exhibited by a region could be influenced by the CE performance exhibited by other regions (Niang *et al.*, 2023).

We found institutions, sectoral composition, human capital and income among the factors that potentially influence regional innovation. These determinants stem from the regional innovation systems and allow us to unveil the social filters of innovation that are critical to raising the regional productivity of innovation (Crescenzi and Rodríguez-Pose, 2013). Among these determinants, we find a positive relationship between institutional quality and regional development, indicating that the role of institutional quality is crucial in explaining regional development (Rodríguez-Pose, 2013). Rodríguez-Pose and Di Cataldo (2015) studied the impact of institutional quality on regional innovation performance with a sample of more than 200 European regions during the period 1997–2009 and found that lower institutional quality hinders innovation at peripheral regions. We find institutional quality to be particularly important with regard to the CE because environmental efforts are highly associated with territorial decentralization and differ within countries (Arauzo-Carod *et al.*, 2022), thereby conferring upon regional data the status of a more accurate glimpse into the geographical spreading of the CE.

After reviewing the relevant research, we found several gaps in the academic literature that need to be filled. In our analysis, we aim to shed light on the geographical spreading of CE in Europe and add to the literature in several ways. First, we build on the absorption of regional CE funds to provide a more comprehensive overview of CE geographical concentration. We do so by estimating the amount of regional funding devoted to CE projects as a proportion of the total regional funding in Europe. Second, we address whether the CE performance is influenced by the performance of neighboring regions, conferring a key role upon spatiality. Third, we describe the socioeconomic factors that may drive the geographical concentration of CE regional funding in Europe, which can be considered crucial to address the existence of a regional divide and convergence issues in terms of the CE as defined by Silvestri *et al.* (2020). Finally, we untangle the existing differences between technology and innovation CE-oriented funds absorption. This may contribute to untangling the complexity associated with the CE (Korhonen *et al.*, 2018). As a consequence, we proceed to define three additional research hypotheses *H2a*, *H2b* and *H2c*:

H2a. The performance of CE in a given region is strongly influenced by the performance of neighboring regions.

H2b. The geographical spread of the CE can be explained by different socioeconomic factors.

H2c. There are differences in the geographical spread of the CE when we distinguish between technology and innovation

3. Data and methodology

3.1 Data

Our database comprises 231 European regions for the year 2014. Our main data source is the ERDF beneficiary's data set produced by Bachtrögler *et al.* (2021) and used by previous studies to yield consistent results (e.g. Santos *et al.*, 2024). The data set includes approximately 600,000 ERDF-funded projects active during the 2014–2020 programing period and provides, among other aspects, information on project geographical location measured at NUTS 2 level of territorial disaggregation; project description, research and innovation taxonomy; and EU co-funding amount. These data were used to estimate our main variable of interest: the average funding concentration of CE projects by NUTS 2 regions in 2014–2020. Given the specific nature of the database, we distinguished between total CE projects, technology CE projects and R&D CE projects. The concentration of CE funds, the dependent variable, refers to the 2014–2020 programing period, whereas the explanatory variables refer to 2014, the first year of the programing period. The logic of this decision is that the factors underlying decision investments by European institutions and policymakers are taken at the beginning of the programing period or during the first years.

Table A1 in the Supplementary material shows the list of economic activities used by Eurostat to produce socioeconomic indicators related to the CE. These activities were used as a baseline to identify potential research projects related to the CE. However, they do not cover all the dimensions included in the CE concept, such as the reduction of waste, residues in the production process or the improvement of the use of products by consumers (e.g. rethinking ownership by sharing or renting). Other techniques, such as text mining on the project description, should be used to identify these CE activities in ERDF-funded projects, as described in subsection 3.2.

We extracted data from several sources at the beginning of the 2014–2020 programing period to explain the focus of the ERDF on the CE projects and to avoid reverse causality bias. We used the European Quality of Government Index estimated by the University of Gothenburg to measure the regional quality of institutions (Charron *et al.*, 2014). The methodology to estimate this indicator of governmental quality is similar to the standard method followed by other international organizations, such as the World Bank. The remaining variables – gross domestic product per capita, share of the population with tertiary education and employment density – were gathered from Eurostat and the Joint Research Centre's Annual Regional Database of the European Commission. The share of employment in economic activities generating the highest amount of waste was estimated using Eurostat Structural Business Statistics data. The economic activities included are, for example, mining and quarrying [general industrial classification of economic activities within the EU (NACE) section B]; electricity, gas, steam and air conditioning supply (NACE section D);

water supply, sewerage, waste management and remediation activities (NACE section E); and construction (NACE section F) [2]. These four economic activities were responsible for 76% of the total waste generated in the EU in 2014 (Eurostat – env_wasgen). Table A4 summarizes the main descriptive statistics for the explanatory variables, and Table A5 shows the correlation matrix.

3.2 Methodology

We followed a three-step methodology to address the study of the CE. The first step was to identify ERDF-funded projects in the field of CE. We combined text-mining analysis by means of keyword search applied to project descriptions with the NACE codes of beneficiaries operating in CE sectors according to the Eurostat classification (see the list in Table A1 in the Supplementary material). These criteria are not mutually exclusive, meaning that a project may be classified as being related to the CE using each criterion alone or in combination. As recent studies show, text mining has become very popular for capturing finer-grained regional differences (de Lucio and Mora-Sanguinetti, 2022). The list of keywords used to identify CE projects included approximately 170 words or expressions linked to the definition and concepts described by Kirchherr *et al.* (2017) and Potting *et al.* (2017), as summarized in Table A2 in the Supplementary material. For more details about the list of keywords, see Table A3 in the Supplementary material. To identify research and innovation CE projects, we combined the Eurostat classification with the classification used in the database of R&D projects created by Bachtrögler *et al.* (2021). We identified all the ERDF-funded CE projects associated with a technology by using the classification in the database created by Bachtrögler *et al.* (2021) associated with key enabling technologies. In addition, we combined this taxonomy with text-mining analysis applied to project descriptions to identify projects related to digital technologies. The list of keywords used for the analysis included approximately 180 words or expressions drawn from keywords extracted from Horizon 2020 call descriptions associated with the theme of digitalization and from the European Science Vocabulary (EuroSciVoc). We also used several synonyms for the keywords extracted from Horizon 2020 calls and EuroSciVoc, which were identified using a thesaurus. These criteria (i.e. inclusion in the key enabling technology taxonomy and in the results of the text-mining analysis) are not mutually exclusive, meaning that a project is classified as related to a technology using each criterion alone or in combination. We then classified ERDF-funded CE projects associated with technology if they were related to the CE and technology.

In the second step, we developed a potential measure of projects funded by CE funds and explored the existence of geographical patterns. We followed Niang *et al.* (2023), who used spatial autocorrelation methodologies to assess CE geographical patterns in French regions. We also explored whether regional CE differences in performance could be found using regional income per capita, which has traditionally been the main indicator for exploring regional polarization, to estimate performance. Nevertheless, it would be desirable to evaluate the specific role of CE actions in relation to the total amount of regional funds, which constitutes an important caveat. Our measure attempts to fill this gap in the recent academic literature by shifting attention to funding related to the role of CE in relation to the total amount of regional funds. In fact, Silvestri *et al.* (2020) argued that CE development could be explained by levels of economic development in which the most disadvantaged regions aim to catch up with more developed regions. However, there has been a recent emphasis on accounting for long-term regional economic stagnation in Europe at different levels of economic development (Diemer *et al.*, 2022). For this reason, it is convenient to introduce additional evidence of indicators that could explain regional differences beyond income per capita.

In the third step, we identified which factors may drive regional funding absorption related to CE initiatives. We drew on variables from prior studies that explain the factors behind the regional concentration of innovation (e.g. Peiró-Palomino, 2019; Rodríguez-Pose and Di Cataldo, 2015). As previously explained, such variables are related to the social filters of innovation, and they are expected to contribute to the regional absorption of funds and, hence, to improving regional capabilities. This approach does have several major shortcomings. First, existing literature has mainly focused on the number of regional patents as the proxy variable to capture innovation efforts. For this reason, it would be desirable to use alternative indicators to measure innovation efforts, such as funding absorption. Second, we enriched the discussion by comparing R&D CE-funded projects with CE technology-funded projects. Technology and innovation share similarities but they may need to be independently addressed to analyze technology in a narrow or a broader sense. Third, we acknowledge that our objective is to shed light on the specific decision to allocate a fraction of R&D-funded projects related to CE. Accordingly, we needed to reframe prior studies by considering Ben-Kheder and Zugravu (2012), who proposed a binary choice model to explain concentration consistent with an economic geography approach. By merging both approaches, we can provide a better glimpse into the factors driving the regional CE funds absorption in the EU.

Our methodological approach builds on a fractional outcome regression model (e.g. Murteira and Ramalho, 2016), which is similar to a standard binary choice regression but offers broader flexibility in the dependent variable, because it can be measured continuously over a defined range rather than being a simple binary choice. Our baseline cross section equation is shown in equation (1):

$$E(CE_i|x_i) = G(x_i, \beta) \tag{1}$$

where $G(.)$ is a nonlinear function, such as $0 \leq G(.) \leq 1$; CE_i is the dependent variable, denoting the fraction of regional R&D funds related to the CE that a region receives, with i denoting the region; the first x_i is the vector of explanatory variables, and β denotes the vector of parameters associated with the explanatory variables. Regarding x_i, this is the vector of explanatory variables: EQI_i is the regional quality of government index; $shEMPw_i$ is the share of employment in economic activities generating the highest amount of waste; $EMPdens_i$ is the regional employment density; $HUMANCAP_i$ is regional human capital; and $GDPpc_i$ is the regional gross domestic product per capita. The concentration of CE funds refers to the 2014–2020 programing period, whereas the explanatory variables refer to 2014, the first year of the programing period.

Regarding institutions, Arauzo-Carod *et al.* (2022) suggested that they are a key factor explaining the geographical spread of the CE. We drew on the prior theoretical frameworks in which high-quality institutions contribute to fostering human capital and innovation efforts (Acemoglu and Robinson, 2012). At the regional level, institutional quality creates adequate incentives for regional stakeholders to make decisions maximizing their technological capabilities (Rodríguez-Pose and Di Cataldo, 2015) and, therefore, may positively contribute to improving CE funds absorption.

Human capital is highly correlated with high-quality institutions (Acemoglu and Robinson, 2012) because this variable also determines knowledge absorption and transmission (Capello and Lenzi, 2018). This is the reason that prior studies have considered human capital as one of the major drivers of innovation (e.g. Peiró-Palomino, 2019;

Rodríguez-Pose and Di Cataldo, 2015). Accordingly, greater human capital could positively affect innovation efforts, and this assumption can be extended to CE projects. Those regions with better human capital endowments could show a greater probability of concentrating CE funds.

We also captured the sectoral composition of the regions in relation to industrial waste production by means of other variables. We considered regional income (Peiró-Palomino, 2019) and employment density (Smol *et al.*, 2017). Larger sizes may be positively associated with the intensity of innovation and, hence – in a context of eco-innovation –with a greater probability of receiving CE funds.

4. Results

Table 1 displays the concentration of CE funds by regions classified according to the cohesion criterion. We measured the concentration of EU funds devoted to CE projects as a percentage of total EU funds received by the region. In contrast, the concentration of CE funds targeted to technology and R&D were measured as a percentage of funds devoted to CE in the region. Data show that less developed regions concentrate a larger percentage of EU funds devoted to CE projects (15.45%). More developed regions target more CE funds to technology and R&D CE projects (68.95% and 40.03%, respectively, as a percentage of CE funds). Some projects can target both technology and R&D. Therefore, geographical patterns constituted a key issue to explore.

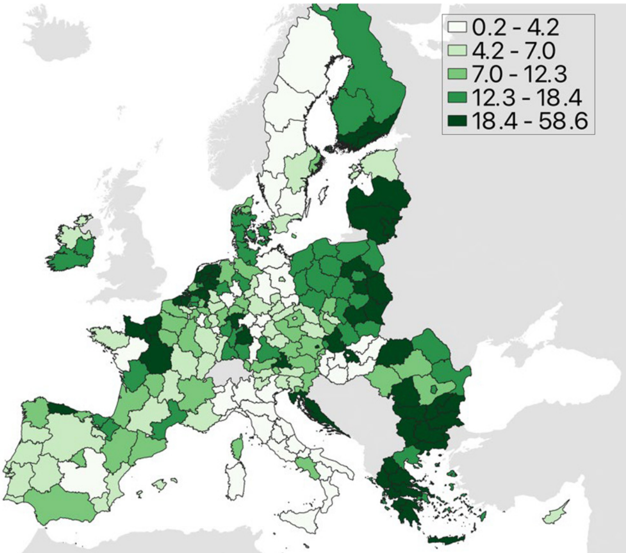
Figures 1–3 illustrate the geographical spread of EU funds devoted to CE projects, CE funds dedicated to technology projects and CE funds devoted to R&D projects (as a percentage of CE funds).

This geographical spreading displayed at Figure 1 can be considered as countervailing if we compare it with the outcomes of previous studies. Our results confirm the existence of a regional agglomeration of CE funds in specific regions from Northern Germany, France, Spain and Italy. These results are in line with Silvestri *et al.* (2020), who found a similar geographical pattern, but they refer to a composite aggregate indicator weighting different socioeconomic dimensions. In contrast, Niang *et al.* (2023) found that employment activities related to CE are geographically distributed across the local level in France, but they did not find the existence of agglomeration patterns. These results confirm our research hypotheses *H1a* and *H1b*; we find a geographical spreading in regional CE performance related to CE funds because of differences in the speed of absorption of regional funds.

Table 1. Concentration of CE funds by regions classified according to the cohesion criterion

Funds	Less developed regions	More developed regions	Transition regions	All regions
EU funds devoted to CE projects (% of EU funds)	15.45	11.01	10.42	12.19
CE funds devoted to technology projects (% of CE funds overall)	62.75	68.95	58.40	64.06
CE funds devoted to R&D projects (% of CE funds)	16.19	40.03	35.51	31.52

Notes: Regions NUTS 2 are classified according to the 2014–2020 categories of region set out in the legislation. Link: https://cohesiondata.ec.europa.eu/browse.This?category=2014+%2F+2020&format=This&limitTo=datasets&sortBy=alpha&tags=categories+of+region
Source: Authors' own elaboration



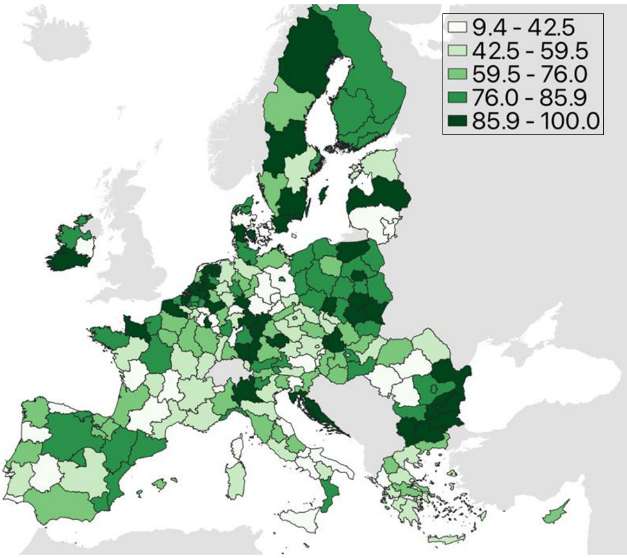
Note: CE funds are measured as a percentage of ERDF funds
Source: EuroGeographics for the administrative boundaries

Figure 1. Geographical pattern of EU funds devoted to CE projects (% of EU funds)

We used the approach proposed by Niang *et al.* (2023), who studied the spatial autocorrelation or the degree of dependency of a region's performance on neighbors' performances, to quantify the degree of spatiality for R&D CE-funded projects for the CE variables. In this paper, there is no possibility to implement a spatial fractional logit because of software limitations. We thus examined whether the CE performance in a region depends on the CE performance in neighboring regions.

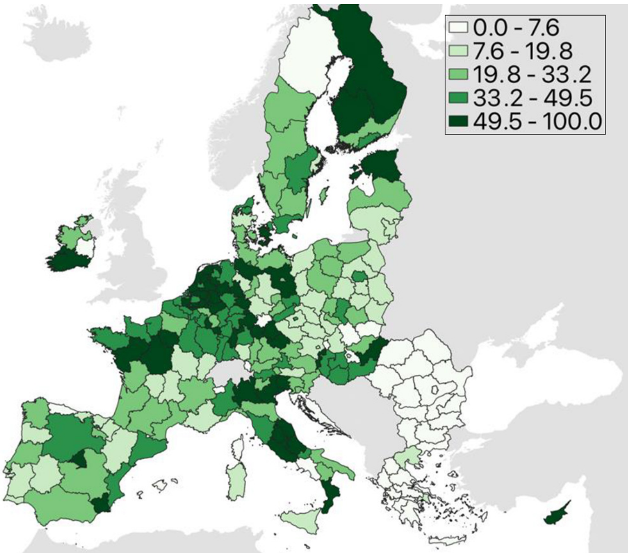
Table 2 shows the results of Moran's I test of global spatial autocorrelation (Moran, 1948). As shown in Table 2, spatial dependence exists for all the CE variables. These results also hold for the other categories of CE-funded projects – technology and overall. A look at our results confirms research hypothesis *H2a* and reveals that a spatial pattern can be found for all European regions, extending the results proposed by Niang *et al.* (2023) for France and conferring a more global scale in terms of explaining the spatiality of the CE. This result is also confirmed by additional tests of spatial dependence, as shown in Table A6 in the Supplementary material. Because the existence of spatial dependence holds, this analysis confirms the robustness of our results.

The second step involved assessing the potential determinants of the R&D CE geographical pattern. Table 3 shows the results for R&D CE funds for technology and overall. It reports the results of the fractional regression model using logit and probit specifications for comparison purposes and robustness. Because both logit and probit are the only functional forms that can fit into the fractional framework described at equation (1), we restricted our robustness analysis to both functional forms. In addition, the Wald chi-squared and log-likelihood test were used to assess the accuracy of our results.



Note: R&D CE funds are measured as a percentage of CE funds
Source: EuroGeographics for the administrative boundaries

Figure 2. Geographical pattern of CE funds devoted to technology projects (% of overall CE funds)



Note: Technology CE funds are measured as a percentage of CE funds
Source: EuroGeographics for the administrative boundaries

Figure 3. CE funds devoted to R&D projects (% of CE funds)

Table 2. Spatial autocorrelation test for the CE measures, NUTS 2 European regions

Variable	Moran's *I*	*p*-value
R&D CE projects (% of total ERDF funding)	0.398	0.000
Technology CE projects (% of total ERDF funding)	0.206	0.000
Total CE projects (% of total ERDF funding)	0.499	0.000

Notes: The *p*-values have been computed using a permutation test with 9,999 random permutations. The critical *p*-value to reject the existence of spatial autocorrelation is 0.05
Source: Authors' own elaboration

A short glimpse at our results reveals that most of the variables are aligned to the expected outcomes derived from the social filters of innovation framework. EQI_i displays a positive association with the concentration of CE funds, regardless of the dimension of CE considered. In relation to employment variables, $shEMPw_i$ is only significant in the model that includes the overall CE funds. Its negative coefficient reveals that the higher the share of employment in economic activities generating the highest amount of waste, the lower the regional concentration of R&D CE funds. In contrast, $EMPdens_i$ (proxy for agglomeration) is positively associated with higher concentrations of R&D and technology CE funds. $HUMANCAP_i$ is also positively associated with most of the cases, and finally, $GDPpc_i$ is positive only for R&D CE funds and is negative for the other groups. As an additional robustness check, we computed the results using simple averages for the explanatory variables during the period 2014–2018, which yielded similar estimates. They can be found in Table A7 of the supplementary Appendix.

Regarding the explanation of our results, we find that the regional quality of institutions can be considered as relevant, highlighting the importance of territorial decentralization when addressing the CE implementation (Arauzo-Carod *et al.*, 2022). We also highlight the negative coefficient of income per capita ($GDPpc_i$) for technology-related and overall CE funds, which not only suggests a potential convergence for the least developed regions (Silvestri *et al.*, 2020) but also that technology cannot be addressed from a narrow perspective and it is necessary to isolate it from innovation to deliver a proper analysis in terms of the CE. These results allow us to test the latter two research hypotheses *H2b* and *H2c*. Regarding *H2b*, we have analyzed that regional funding concentration of CE projects is driven by different socioeconomic factors. We also find differences between R&D and technology CE funding, which is in line with hypothesis *H2c*.

5. Discussion and conclusions

In this paper, we have explored the geographical spreading associated with the CE. We examined the share of R&D CE funds in the 2014–2020 programing period, discovering the existence of a geographical pattern for European regions. We identified the factors that drive such regional patterns using a fractional response model. The results suggest that variables such as the regional quality of government, employment, human capital and income per capita are fundamental because they may be driving the geographical distribution of R&D CE projects. Our results also reveal the existence of a spatial pattern in which the CE performance in a region could be influenced by the CE performance in neighboring regions. We found differences between regional funds devoted to CE projects overall, to technology projects and to R&D projects, suggesting that addressing CE at the subnational level is complex.

Table 3. Fractional logit and probit results for R&D, technology and overall CE funds

Type of CE fund	R&D		Technology		Overall	
Fractional regression	Probit	Logit	Probit	Logit	Probit	Logit
EQI_i	0.220*** (0.081)	0.364*** (0.140)	0.156** (0.065)	0.249** (0.105)	0.143*** (0.052)	0.271*** (0.104)
Log of $shEMPw_i$	0.003 (0.171)	−0.026 (0.299)	0.145 (0.172)	0.233 (0.276)	−0.347*** (0.121)	−0.656*** (0.224)
Log of $EMPdens_i$	0.088** (0.042)	0.142** (0.069)	0.066* (0.039)	0.106* (0.063)	0.033 (0.029)	0.067 (0.055)
Log of $HUMANCAP_i$	−0.200 (0.144)	−0.330 (0.242)	0.363** (0.144)	0.587** (0.234)	0.428*** (0.091)	0.793*** (0.174)
Log of $GDPpc_i$	0.277** (0.135)	0.452* (0.235)	−0.297*** (0.115)	−0.473*** (0.183)	−0.550*** (0.095)	−1.038*** (0.177)
Intercept	−3.313** (1.372)	– 5.480** (2.411)	4.332*** (1.158)	6.912*** (1.848)	4.052*** (0.866)	7.847*** (1.624)
Observations	231	231	231	231	231	231
Wald chi-squared test	83.132	78.249	17.299	17.284	58.472	61.093
Log-likelihood	−135.464	−135.574	−149.166	−149.181	−83.414	−83.389
Pseudo R^2	0.059	0.058	0.011	0.011	0.026	0.026

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Numbers in brackets denote robust standard errors. The concentration of CE funds refers to the 2014–2020 programing period, whereas explanatory variables refer to 2014

This analysis reveals important policy recommendations that, if followed, can contribute to expanding our knowledge of the geographical spread of the CE. Allocating regional funds to CE may contribute to fostering a new regional growth paradigm that breaks with the traditional linear production model by introducing sustainability as a new source of competitive advantage and a convergence path. At the same time, the green transition could contribute to a rise in territorial inequalities (Rodríguez-Pose and Bartalucci, 2024). European institutions become a fundamental actor to manage the funds to achieve a more prosperous future European Union. The CE could be used as a tool prior to place-based policies that aim to avoid the regional development trap.

Several caveats arose concerning a proper analysis of the CE that may constitute challenges for academics and policymakers. Perhaps the most important one is related to the absence of official statistics and measures, thereby impeding the setting of adequate follow-up targets by regional authorities. Future research efforts might delve into exploring these research findings using alternative measures of the CE at the regional level, as in previous studies (Segarra-Blasco *et al.*, 2024; Smol *et al.*, 2017). It would also be desirable to explore these findings using panel data methodologies because regions can improve their CE performance by enhancing their socioeconomic determinants over time.

Notes

1. Data were extracted on 21 June 2023 from the European Commission’s Cohesion Open Data Platform.
2. We use the EU-27 data from Eurostat (env_wasgen) referring to 2014 to identify the economic activities with the highest contribution to waste generation.

References

Acemoglu, D. and Robinson, J. (2012), *Why Nations Fail: The Origins of Power, Prosperity and Poverty*, Profile Books, London.

Arauzo-Carod, J.M., Kostakis, I. and Tsagarakis, K.P. (2022), “Policies for supporting the regional circular economy and sustainability”, *The Annals of Regional Science*, Vol. 68 No. 2, pp. 255-262.

Bachtrögler, J., Arnold, E., Doussineau, M. and Reschenhofer, P. (2021), “Update: dataset of projects co-funded by the ERDF during the multi-annual financial framework 2014–2020”, Publications Office of the European Union, Luxembourg, JRC125008.

Ben-Kheder, S. and Zugravu, N. (2012), “Environmental regulation and French firms location abroad: an economic geography model in an international comparative study”, *Ecological Economics*, Vol. 77, pp. 48-61.

Bourdin, S. and Torre, A. (2020), “The circular economy as a means of territorialisation of the EU industry”, *Symphonya: Emerging Issues in Management*, Vol. 2 No. 2, pp. 33-40.

Capello, R. and Lenzi, C. (2018), “Knowledge, innovation and productivity gains across European regions”, *Geography of Innovation*, Routledge, London, pp. 22-38.

Charron, N., Dijkstra, L. and Lapuente, V. (2014), “Regional governance matters: quality of government within European Union Member States”, *Regional Studies*, Vol. 48 No. 1, pp. 68-90.

Crescenzi, R. and Rodríguez-Pose, A. (2013), “R & D, socio-economic conditions, and regional innovation in the U.S”, *Growth and Change*, Vol. 44 No. 2, pp. 287-320.

de Lucio, J. and Mora-Sanguinetti, J.S. (2022), “Drafting ‘better regulation’: the economic cost of regulatory complexity”, *Journal of Policy Modeling*, Vol. 44 No. 1, pp. 163-183.

Diemer, A., Iammarino, S., Rodríguez-Pose, A. and Storper, M. (2022), "The regional development trap in Europe", *Economic Geography*, Vol. 98 No. 5, pp. 487-509.

European Commission (2023), "European structural and investment funds – 2022 summary report of the programme annual implementation reports covering implementation in 2014–2020", Brussels.

Hekkert, M.P., Suurs, R.A., Negro, S.O., Kuhlmann, S. and Smits, R.E. (2007), "Functions of innovation systems: a new approach for analysing technological change", *Technological Forecasting and Social Change*, Vol. 74 No. 4, pp. 413-432.

Iammarino, S. (2005), "An evolutionary integrated view of regional systems of innovation: concepts, measures and historical perspectives", *European Planning Studies*, Vol. 13 No. 4, pp. 497-519.

Kirchherr, J., Reike, D. and Hekkert, M. (2017), "Conceptualizing the circular economy: an analysis of 114 definitions", *Resources, Conservation and Recycling*, Vol. 127, pp. 221-232.

Korhonen, J., Honkasalo, A. and Seppälä, J. (2018), "Circular economy: the concept and its limitations", *Ecological Economics*, Vol. 143, pp. 37-46.

Krugman, P. (1991), "Increasing returns and economic geography", *Journal of Political Economy*, Vol. 99 No. 3, pp. 483-499.

Miguélez, E. and Moreno, R. (2015), "Knowledge flows and the absorptive capacity of regions", *Research Policy*, Vol. 44 No. 4, pp. 833-848.

Moran, P. (1948), "The interpretation of statistical maps", *Journal of the Royal Statistical Society: Series B (Methodological)*, Vol. 10 No. 2, pp. 243-251.

Murteira, J.M. and Ramalho, J.J. (2016), "Regression analysis of multivariate fractional data", *Econometric Reviews*, Vol. 35 No. 4, pp. 515-552.

Niang, A., Bourdin, S. and Torre, A. (2023), "The geography of circular economy: job creation, territorial embeddedness and local public policies", *Journal of Environmental Planning and Management*, Vol. 67 No. 12, pp. 1-16.

Peiró-Palomino, J. (2019), "The geography of social capital and innovation in the European union", *Papers in Regional Science*, Vol. 98 No. 1, pp. 53-73.

Potting, J., Hekkert, M., Worrell, E. and Hanemaaijer, A. (2017), Circular economy: measuring Innovation in the Product Chain, Policy Report, PBL Netherlands Environmental Assessment Agency, The Hague.

Rodríguez-Pose, A. (2013), "Do institutions matter for regional development?", *Regional Studies*, Vol. 47 No. 7, pp. 1034-1047.

Rodríguez-Pose, A. and Bartalucci, F. (2024), "The green transition and its potential territorial discontents", *Cambridge Journal of Regions, Economy and Society*, Vol. 17 No. 2, pp. 339-358.

Rodríguez-Pose, A. and Di Cataldo, M. (2015), "Quality of government and innovative performance in the regions of Europe", *Journal of Economic Geography*, Vol. 15 No. 4, pp. 673-706.

Sachs, J.D. (2015), *The Age of Sustainable Development*, Columbia University Press, Columbia.

Sala-I-Martin, X. (1996), "Regional cohesion: evidence and theories of regional growth and convergence", *European Economic Review*, Vol. 40 No. 6, pp. 1325-1352.

Santos, A.M., Conte, A. and Molica, F. (2024), "Financial absorption of cohesion policy funds: how do programmes and territorial characteristics influence the pace of spending?", *JCMS: Journal of Common Market Studies*, doi: 10.1111/jcms.13640.

Segarra-Blasco, A., Teruel, M. and Tomàs-Porres, J. (2024), "Circular economy and public policies: a dynamic analysis for European SMEs", *Business Strategy and the Environment*, Vol. 33 No. 4,

Silvestri, F., Spigarelli, F. and Tassinari, M. (2020), "Regional development of circular economy in the European Union: a multidimensional analysis", *Journal of Cleaner Production*, Vol. 255, p. 120218.

Smol, M., Kulczycka, J. and Avdiushchenko, A. (2017), "Circular economy indicators in relation to eco-innovation in European regions", *Clean Technologies and Environmental Policy*, Vol. 19 No. 3, pp. 669-678.

Zahra, S.A. and George, G. (2002), "Absorptive capacity: a review, reconceptualization, and extension", *The Academy of Management Review*, Vol. 27 No. 2, pp. 185-203.

Supplementary material

The supplementary material for this article can be found online.

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