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Horizon Europe: a green window of opportunity for european peripheral regions?

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Abstract An emerging field of research suggests that the policy and societal pressures for a green transition represent a "green window of opportunity" for peripheral regions. These regions often lag behind in overall innovation performance and may suffer from being places that don't matter. At the same time, these are exactly the regions that the European Union is trying to support through several programmes, including Horizon Europe. This paper investigates the participation of organisations from peripheral regions in environmental projects funded by the Horizon Europe programme. To account for the multidimensional nature of regional peripherality, we define peripheral regions from a geographical, innovation and socio-economic perspective. We then analyse the relationship between these dimensions of regional peripherality and the extent to which regions benefit from Horizon environmental innovation projects in terms of participation, amount of funding and position in the overall network of project consortia.

Our findings show a greater participation in Horizon environmental innovation projects for regions in Southern and Northern Europe, while within-country peripherality is negatively related to participation. At the same time, regions that are lagging in terms of innovation and socio-economic performance also receive less of this specific funding. Overall, geographical peripherality only tells a part of the story as several "places that don't matter" for innovation and economic dynamism are also unable to benefit from these specific green windows of opportunity.

Keywords Environmental innovation · Horizon Europe · Peripheral regions · Regional integration

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1 Introduction

The European Union (EU) aims to achieve a fully "circular, carbon neutral, and sustainable" economy by 2050 (European Commission and Directorate General for Research and Innovation 2021b). Accomplishing this goal require changes to European production systems and technological capabilities, as well as economic and societal transformations. With an unprecedented budget of €95.5 billion, Horizon Europe, the ninth European Research and Innovation Framework Programme of the EU (2021–2027), is one of the instruments set up by the EU to achieve sustainability goals. "Climate, Energy, and Mobility", one of the programme's top priority areas, has a budget of €15 billion, which places sustainability at the forefront of the EU's innovation agenda (European Commission and Directorate General for Research and Innovation 2021b).

International cooperation in research and innovation is another strategic priority of Horizon Europe (European Commission and Directorate General for Research and Innovation 2021b). The Horizon Europe Strategic Plan (2021b), in line with European Cohesion policy, aims to create opportunities in new and emerging markets by promoting international research cooperation (European Commission and Directorate General for Research and Innovation 2021b). Encouraging international cooperation may be particularly beneficial for European peripheral regions. These regions are often challenged by lower levels of economic activity and geographical isolation (Iammarino et al. 2019; McCann and Soete 2020). Facilitating lagging regions' access to innovation networks may also be useful to overcome the regional innovation paradox in Europe, "the apparent contradiction between the comparatively greater need to spend on innovation in lagging regions and their relatively lower capacity to absorb public funds (...) and to invest in innovation related activities" (Oughton et al. 2002, p. 2).

An emerging field of study suggests that the renewed focus on green transitions presents a unique "window of opportunity" for peripheral regions to "leapfrog" into environmental innovation, i.e. to quickly catch up towards the development and adoption of green technologies and practices, and to further cultivate their innovation systems (Marchi et al. 2013; Yap and Truffer 2019; Lema et al. 2021; Gong et al. 2022). Creating extra-regional collaborations can help to overcome some of the biggest challenges in the leapfrogging process by providing organisations with the resources and opportunities they need to accelerate the development and adoption of green technologies and practices, and to catch up with more established players in the field (Barzotto et al. 2019; Grillitsch and Hansen 2019).

The subset of projects funded by Horizon Europe under the "Climate, Energy and Mobility" priority area offers a unique testbed to examine the extent to which peripheral regions are able to seize such windows of opportunity for collaboration and funding of environmental innovation projects. The programme's open data provides information into the regional distribution of environmental projects, allowing testing the theoretical expectations derived from the green windows of opportunity literature. In this paper, we use this data to investigate the position of peripheral regions in green research and innovation projects within the Horizon Europe framework, and assess whether the programme is presenting unique green windows of opportunity for innovation in these regions. Hence, our paper's main research question is: *Is there a relationship between peripherality and regional participation in Horizon Europe funded environmental innovation projects?*

Previous studies have analysed the distribution of funds in various European Framework Programmes for Research and Development (EU-FPs) over extended periods of time (see for instance Balland and Boschma 2021; Meliciani et al. 2022; Scherngell and Barber 2009). This study adopts a unique approach by focusing on the ongoing Horizon Europe programme, which has only been in operation since 2021, and by specifically analysing projects under the "Climate, Energy and Mobility" priority area (referred to as "environmental projects" in this paper). This priority area aims to support research and innovation to "fight climate change by better understanding its causes, evolution, risks, impacts and opportunities, and by making the energy and transport sectors more climate and environment-friendly (...)" (European Commission and Directorate General for Research and Innovation 2021b). Furthermore, our analysis is primarily centred on the role and positioning of peripheral regions within this priority area. By combining the topic of environmental innovation and regional peripherality, our approach enables a specific understanding of green windows of opportunities that arise from the Horizon Europe programme.

Sustainability is a problem of the commons, which means it requires collective action to address it. Understanding how to ensure that environmental innovation is spread evenly and no region is left behind is essential for achieving an inclusive and equitable transition to a sustainable future. By researching the integration of peripheral regions in environmental projects, this paper has the potential to provide valuable insights for policymakers and practitioners on the effectiveness of Horizon Europe in promoting regional integration. The results of this study may also shed light on how certain regions benefit from Horizon Europe more than others, and suggest ways to encourage a more equitable distribution of benefits.

2 Research background

2.1 Regions and peripherality

The definition of peripheral regions encompasses multiple dimensions that are interconnected. For the purpose of this paper, we will narrow down the focus to three main dimensions of peripherality: geography, innovation capacity, and socio-economic conditions. Viewed from the geographical perspective, peripheral regions are characterised by their remoteness from urban centres, by being relatively scattered, with a low population density, and more disconnected compared to central regions (Dubois and Roto 2013; Pugh and Dubois 2021; Glückler et al. 2023). Their location and relative sparsity might prevent them to profit from some of the benefits associated with agglomeration, i.e. the clustering of economic activities, industries, and people (Rosenthal and Strange 2004; Pugh and Dubois 2021).

Taking an innovation and socio-economic perspective, Iammarino et al. (2019, p. 281) say peripheral regions are characterised by “low employment rates, poor quality of government and low investment in R&D”. Peripheral regions also tend to have a lower innovation capacity, and are characterised by having single-product economies and technological underdevelopment compared to core regions (Malecki 1997; Farole et al. 2011; Eder 2019). Due to these factors, many peripheral regions suffer from long-term declines in competitiveness, and have lower capabilities to absorb and seize innovation opportunities (Corradini 2019; Iammarino et al. 2019). In Europe, these regions tend to be located in Eastern and Southern Europe (Iammarino et al. 2019).

“Core regions”, on the other hand, are considered to be at the “centre” of Europe, both geographically and economically (Iammarino et al. 2019). These regions tend to be more developed and have higher levels of economic activity, including industrial production and innovation, compared to peripheral regions. They often have strong connections to other core regions and are considered to be centres of power and influence (Iammarino et al. 2019). In Europe, these regions are normally located in Western Europe and include countries such as Germany, France and the Netherlands.

2.2 Peripherality and regional innovation

Peripheral regions have both facilitating and inhibiting factors when it comes to developing new innovation paths (see Table 1 for an overview). The inhibiting factors have tended to receive more attention so far: peripheral regions may face difficulties due to a lack of endogenous innovation capabilities and having low resource endowments for creating high-growth economic activities (Farole et al. 2011; Gong et al. 2022). Compared to organisations located in agglomerations, with a developed knowledge infrastructure, organisations in the peripheries are also less likely to benefit from local knowledge spillovers (Grillitsch and Nilsson 2015). Moreover, peripheries may suffer from poor quality of institutions, lower support for innovation and entrepreneurship, and a lack of dynamic clusters and support organisations (Tödtling and Trippl 2005).

Recent literature has started to uncover those factors that instead facilitate innovation in the periphery (Eder 2019). One potential benefit of peripherality is that it might mitigate the risk of lock-ins—rigid, constricting structures that can stifle the development of innovation—which gives peripheral organisations more flexibility

Table 1 Facilitating and inhibiting factors for innovation in peripheral regions

Facilitating factors	Inhibiting factors
Less lock-ins	Lack of endogenous innovation capacity
Institutional leeways	Low support for innovation
Access to natural resources	Poor resource endowments
Larger reliance on local knowledge	Low institutional quality
Prevents know-how outflow to competitors	Limited knowledge spillovers
Supports slow innovation and hidden champions	Lack of dynamic clusters
	Lower human capital

and agility to explore new ideas (Grillitsch and Hansen 2019; Gong et al. 2022). Institutional voids, described as the absence of formal institutions to guide economic development, may also exist in these areas. Although institutional voids could create challenges for peripheral regions, they may also encourage local businesses to develop their own solutions with more flexibility (Gong et al. 2022). Furthermore, some of these regions might have access to natural resources, such as renewable energies, which are deemed crucial for green transitions (Grillitsch and Hansen 2019). These regions also tend to be better equipped to capitalise on local knowledge, and their peripherality may restrict competitors from accessing their expertise, as well as encouraging peripheral organisations to compensate their remoteness by fostering closer relationships with extra-regional actors (De Marchi 2012; Grillitsch and Hansen 2019).

When peripheral regions do not show a critical mass in any particular industry or are specialised in "dirty" industries, developing new industries from existing ones can be a difficult form of path development towards environmental innovation. The biggest challenge in the leapfrogging process of peripheral regions will be setting up the conditions for the implementation of new technology fields (Grillitsch and Hansen 2019). An additional challenge is that inability to access knowledge spillovers which might concentrate in core, urban regions (Rodríguez-Pose and Wilkie 2019; Filippopoulos and Fotopoulos 2022).

However, innovation can also occur outside of cities. "Fast innovation", which relies on knowledge with a short life or a rapid decay, tends to benefit from frequent and intense interactions associated with agglomeration, whereas for "slow innovation", which relies on slowly decaying information, the benefits of agglomeration might not be as pronounced (Shearmur 2015). Examples of innovation occurring outside of agglomerations include "hidden champions"—normally small and family-owned companies that operate outside of cities, and are still successfully competing in global markets. Found in Germany, but also typical of several other European countries, these "hidden champions" are significant drivers of socio-economic development and innovation outside of urban agglomerations (Vonnahme and Lang 2021).

Creating extra-regional collaborations and linkages may help to create the necessary conditions for the adoption of new technologies. This strategy is often suggested to improve regional innovation systems and as a major vehicle for knowledge exchange among organisations that are located in the peripheries (e.g., Graf 2011; Barzotto et al. 2019; Grillitsch and Hansen 2019; Meliciani et al. 2022). For instance, Balland and Boschma (2021) have suggested that interregional linkages have positive effects on the probability that peripheral regions will exploit new innovation activities. Similarly, Rodríguez-Pose and Wilkie (2019) found that exposure to short- and long-distance interregional knowledge flows is relevant for innovation in European peripheral regions. Networks of research and collaboration, informal knowledge exchange, and labour mobility can develop knowledge spillovers regardless of distance, and facilitate combining local knowledge with that held elsewhere (Filippopoulos and Fotopoulos 2022).

As a result, strengthening interregional networks and linkages with key players and research institutions is often recommended to develop peripheral innovation capabilities (e.g., Yap and Truffer 2019; Grillitsch and Hansen 2019; Filippopoulos and Fotopoulos 2022; Kamath et al. 2022). When analysing inter-organisational collaboration for environmental innovation, Sharma and Kearins (2011) found that collaborating allowed organisations to share ideas, implement new approaches, and develop relevant relationships and new capacities. Bossink (2018) also found that firms are more likely to develop environmental innovations when working together in networks.

Nevertheless, while collaboration is often seen as an ideal mechanism for developing environmental innovation, it may not always be effective or efficient in practice. Collaboration is complex and might be prone to communication issues (Sharma and Kearins 2011), and peripheral regions often have limited institutional structures and weak clustering, which may prevent them from joining networks (Tödtling and Trippl 2005). Innovation and research framework programmes in the European Union, such as Horizon Europe, creates a network of relations between projects and entities, enabling the exchange of information and expertise (Calvo-Gallardo et al. 2022) and could enhance the integration of peripheral regions in extra-regional knowledge flows.

2.3 Green windows of opportunity for innovation

The distribution of core and peripheral regions across the continent, along with their varying capacities for innovation, raises important questions about the potential for environmental innovation in these regions. Sbardella et al. (2022) examined the distribution of innovation activities in the EU and found that regions with the highest potential for environmental innovations are located in Central and Western Europe, with a particular focus on Germany. Regions on the periphery of Europe tend to be weaker in developing environmental innovation, which could result in core regions, that are more technologically advanced, benefiting the most from the changes brought about by green transitions (McCann and Soete 2020).

This does not mean, however, that peripheral regions cannot develop their own environmental innovation systems. There are significant complementarities between current and green technologies in regions that have not yet developed a focus on them (Sbardella et al. 2022). Additionally, some studies suggest that the current transitional context, characterised by a growing recognition of the need to move away from environmentally harmful practices and towards more green-friendly alternatives, creates "green windows of opportunity" for economic development in peripheral regions (e.g., Gong et al. 2022; Yap and Truffer 2019). Such opportunities are defined as the "process by which latecomers proactively translate globally foreseeable opportunities or threats into a specific selection environment that privileges certain technological trajectories" (Yap and Truffer 2019, p. 1031).

Green windows of opportunity emerge when changes to technological regimes lower entry barriers and learning times facilitating the catch-up with leading players (Lema et al. 2021). The incentives for developing environmental innovation in peripheral regions are twofold: on the one hand, regions could benefit from the growing economic interest in these kinds of technologies, improve their international competitiveness and avoid energy dependencies. On the other hand, environmental innovation would contribute to addressing the local and global challenge of reducing environmental impacts (Marchi et al. 2013; Yap and Truffer 2019). Although this study field is still relatively new and empirical research is needed to fully understand the mechanisms that support the growth of environmental innovation in peripheries, it has rapidly attracted substantial interest and recognition (Gong et al. 2022).

According to Perruchas et al. (2020) regions tend to diversify their innovation towards green technologies that align with their existing competencies. Environmental innovations frequently result from the recombining of heterogeneous pieces of knowledge and technologies in novel ways (Barbieri et al. 2023). Regions with low levels of green technologies may face challenges in taking advantage of potential windows of opportunity, as the degree of green maturity, the extent to which green technologies are commercially available and widely adopted, has proven to be more important for diversifying towards green than the overall level of development (Perruchas et al. 2020).

Regions with low green maturity might be under two circumstances: they might be regions specialised in a "dirty" industry, or regions with a lack of any particular specialisation. For regions specialised in a "dirty industry", Grillitsch and Hansen (2019) recommend transforming existing knowledge into green with path upgrading, "a major qualitative change of existing industries", and path diversification, "a development from existing industries into new ones by applying existing knowledge in new industries". The implementation of these two strategies could open up avenues for the development of green activities that depart from traditional "dirty" industries, creating new opportunities for environmental innovation and growth.

Peripheral regions can also develop environmental innovations through path emergence, "the development of green industries unrelated to existing ones" by deploying green technologies developed elsewhere. The strategy that these regions would need to follow is "leapfrogging", which consists of taking advantage of the changing circumstances to "jump" into new green industries through path emergence (Gong et al. 2022; Lema et al. 2021).

Developing environmental innovations, however, is not automatic and will depend on the efforts of firms and institutions to develop appropriate technologies (Lema et al. 2021). Traditional catch-up studies suggest that the industrial policies formulated by the government are highly influential in the latecomer industrial development, and that firms typically operate within the national framework conditions provided by these policies (Bernhard 2016; Lema et al. 2021). Nevertheless, policies are not the only drivers of innovation, as firms can also push for preferred technology trajectories directly, thus "endogenising windows of opportunity" (Yap and Truffer 2019). Horizon Europe could facilitate the development of environmental innovation for latecomers both by formulating policies that promote cooperation and funding for environmental innovation, and by providing companies and research institutions with the opportunity to choose their own technology trajectories.

2.4 The geography of Horizon Europe funding

The European Commission (Council of the European Union 2022) contends that the EU's green transition must be inclusive and direct special attention to those regions that will face the biggest challenges. Horizon Europe recognises the need for more collaboration across borders and will devote the majority of its funds to projects with transnational consortiums of beneficiaries (European Commission and Directorate General for Research and Innovation 2021b).

The "Widening Participation and Spreading Excellence" strategy under Horizon Europe aims to contribute to building innovation capacity in regions "lagging behind" (European Commission and Directorate General for Research and Innovation 2021b). This strategy has a number of mechanisms to support the integration of peripheral regions, which include enhancing networking activities between research institutions in peripheral regions and top-class counterparts, providing support for dissemination and exploitation of research findings, allowing research institutions from peripheral regions to join ongoing research and innovation actions, and creating innovation ecosystems through robust linkages between academia, businesses, governments, and civil society (European Commission and Directorate General for Research and Innovation 2021b). Moreover, the "Widening" priority will be one of the points into consideration when evaluating project proposals with the goal of developing role models to stimulate excellence, new investments and reforms, help peripheral innovators access networks, as well as develop visibility and upskill staff (European Commission and Directorate General for Research and Innovation 2021b).

The analysis of European Framework Programmes for Research and Technological Development (EU-FPs) have shown mixed effects in regards to distance and the likelihood for collaboration. Paier and Scherngell (2011), for instance, found that in previous EU-FPs inter-organisational collaborations were facilitated by prior acquaintance, thematic and geographic proximity. Similarly, Balland et al. (2019) and Balland (2012) found that geographic and cultural proximity, the size of the country, and network centrality, all had positive impacts on the propensity of countries to participate in research collaborations. Amoroso et al. (2017) also found that networks created in the 7th EU-FP programme mainly connected regions in proximity, and similar regions in terms of physical, institutional, social and technological characteristics. On the other hand, Autant-Bernard et al. (2007) found that geographical distance was not as important as social distance to explain collaborations in the 6th EU-FP.

Another relevant finding of Balland et al. (2019) is that the core of the collaboration networks in EU-FPs is mainly formed by EU-15 participants—particularly Germany, France, the UK, Italy, and Spain—while EU-13 countries are often on the outskirts of the network. Similarly, Breschi and Cusmano (2006) find that the network created by EU-FPs is highly hierarchical, with a core group of frequent participants with more connections, linked to a large number of peripheral actors. Calignano (2021) found that within country innovativeness played a more important role than innovativeness within the EU as a whole in determining central positions in the networks of innovation projects. In addition, regional socio-economic conditions, the 'strength' of the regional knowledge base, and the type of industry represented in the programme together shaped the distribution of innovation projects and the position of regions (Calignano 2021; Wanzenböck et al. 2020; Wanzenböck and Scherngell 2013). Overall, peripheral regions had lower rates of collaboration compared to other regions (Amoroso et al. 2017).

Regions benefit from the participation in EU-FPs in varying ways. In regions of older EU member states and capital areas in Central and Eastern European countries, this research funding tends to replace funding from other sources. Instead, less developed parts of Central and Eastern Europe, leverage more the external knowledge from EU-FPs research networks due to less advanced local knowledge systems (Varga and Sebestyén 2017). Peripheral regions that become involved in research networks benefit from the exchange of knowledge and are thus provided with an opportunity to overcome the challenges posed by distance and by being located in more remote locations (Meliciani et al. 2022). Academics and experts participating in collaborative projects share ideas and best practices, influence each-others work, and connectivity has a positive effect on economic growth (Paier and Scherngell 2011; Meliciani et al. 2022). Additionally, as discussed earlier, leapfrogging might be a promising way for peripheral regions to develop their innovation systems in a sustainable manner. Some authors (e.g., Broekel 2015; Silvestri et al. 2020) suggest that R&D subsidies to promote collaboration, such as Horizon Europe, might play an important role in stimulating innovation in these European regions.

When it comes to environmental innovation projects, the green window of opportunity hypothesis would suggest that peripheral regions have an advantage in accessing the specific funding focused on environmental projects. Yet, empirical evidence on this specific set of projects is lacking and our study aims to fill this gap.

3 Research design

3.1 Data and variables definition

This paper utilises data from Horizon Europe projects within the "Climate, Energy, and Mobility" thematic priority. This thematic priority, Cluster 5 of Horizon Europe, promotes research and innovation aimed at fighting climate change and making energy and transport more efficient and sustainable (European Commission 2021b). The data was retrieved from Horizon Dashboard, a platform that provides information about signed grant agreements in the EU's Framework Programmes since 1983 (European Commission 2023).

The dataset extracted for this study includes information on the project identifiers, participants, their locations, and the amount of funding they received. Firstly, the dataset includes the title and ID of projects within the Horizon Europe green priority, and the signature year (all projects were signed in 2022). Secondly, the dataset includes the name and ID of participants. Thirdly, the dataset reports whether the participant is an EU member state or not, and the country, region, and city where the participant is located. Finally, the dataset includes information on the Horizon Europe's funding to each participant in euros.

We later merged the information of the regions' names with their NUTS2 codes to have a unique standard identifier for each participant's regions. NUTS0 was used as the reference for countries without NUTS2. These include Cyprus, Estonia, Ice-

Table 2 Concepts and indicators of peripherality included in the analysis

Indicator	Description	Concept
Regional population density, 2019	Ratio between the annual average population and the land area of the region (Eurostat 2023c)	Geographical peripherality
Distance to capital (km)	Distance of the centre of each region to the countries' capital city	Geographical peripherality
Distance to EU centre—Bruxelles (km)	Distance from each region's geographical centre to the political centre of the EU, Bruxelles	Geographical peripherality
Europe macro-regions	Eastern, Southern, Northern and Western Europe, according to the classification in EuroVoc (Publications Office of the European Union 2023)	Geographical peripherality
Regional Innovation Scoreboard (RIS), 2021	Multi-indicator index to evaluate and compare the innovation performance and capabilities of European regions (European Commission et al. 2021a). RIS primarily relies on 2019 data or the most recent year available (European Commission et al. 2021a)	Innovation peripherality
Regional intramural R&D expenditure (GERD) (%), 2017	Total amount of R&D expenditure as a percentage of the region's gross domestic product (GDP) (Eurostat 2023a)	Innovation peripherality
Regional gross domestic product per inhabitant (GDP per capita), 2019	Total value of goods and services produced in a region divided by the number of inhabitants (Eurostat 2023d)	Socio-economic peripherality
Regional proportion of population with tertiary education (%), 2019	Share of each region's population that has completed tertiary education (Eurostat 2023b)	Socio-economic peripherality
Regional unemployment rate, 2018	Share of unemployed individuals in the economically active population per region (Eurostat 2023e)	Socio-economic peripherality

land, Lichtenstein, Latvia, Luxemburg, Malta, Montenegro and North Macedonia. The participants outside Europe were deleted from the dataset. The final dataset comprises 296 projects and 2,514 unique participants from 263 European regions. The information was reorganised by using NUTS2, NUTS0 in the cases indicated above, as the primary unit of analysis and aggregating the regional number of participations and funding received. Then, we incorporated various regional indicators and measures in the dataset to evaluate the peripherality of each region selecting for each the latest year available with complete information.

As already discussed, we adopt a multidimensional definition of regional peripherality. The indicators in Table 2 capture peripherality in geographical terms, as well as innovation and socio-economic performance:

- Indicators under the concept of "Geographical peripherality" aim to measure the degree of remoteness of the region considering regional sparsity (population density), national terms (distance to national capital), and absolute terms (distance to EU centre and macro-region)

- The concept of "Innovation peripherality" encloses indicators that reflect peripherality in terms of innovation performance (RIS), as well as regional expenditure in research and development (GERD).
- Indicators under the "Socio-economic peripherality" concept are aimed to capture peripherality in economic terms (GDP per capita), human capital (tertiary education) and quality of the labour market (unemployment).

The models proposed in this study also integrate three control variables: overall regional funding from the Horizon Europe programme, regional green technology, and pollution. The funding from the Horizon programme reflect the amount of funding allocated to each region in all the different thematic areas of Horizon Europe. Regional green technology is based on the Green Tech Indicator (Perruchas et al. 2020), derived from the analysis of patents filed at the regional level utilising the ENV-TECH classification system developed by the OECD and drawing upon PATSTAT data from 2016. The third indicator, Regional Air Quality Health Risk Assessment (AQRA) (European Environment Agency 2022), measures the health risk for exposure to three pollutants normally derived from industrial processes (PM2.5, NO2, and O3-SOMO35) at the regional level, along with the average and population-weighted concentration values for other pollutants. The dataset reflects pollution levels from 2019 or the latest year available.

The models with regional funding from Horizon Europe as the dependent variable include the same indicators in Table 2, but replace the control variable environmental patents with the number of regional patent applications from 2019 or latest year available (retrieved from REGPAT). It should be noted that the data used for the key independent variables covers different years, chosen due to data availability and comprehensiveness. This is a limitation of the dataset, which combines several different data sources. At the same time, all years precede the start of Horizon Europe funding in 2021, which helps to account for endogeneity and consider regional conditions prior to the funding.

3.2 Methodology

3.2.1 Descriptive analysis of Horizon Europe data

The first step is a descriptive analysis of Horizon Europe's environmental projects. First we created a scatterplot that illustrates the regional funding to all Horizon Europe projects compared to the funding to environmental projects, focusing on the four different macro-regions.

Additionally, we mapped the number of participations that each region had in environmental projects within Horizon Europe. "Participation" refers to the number of times an organisation (incl. universities, research centres, business, non-for-profits and government agencies) in a given region is a partner in a project; for example, if an organisation is involved in five projects, it has five participations. The total number of participations per region is calculated by aggregating the participation of all organisations within that region. We also compiled the total amount of Horizon Europe funding received in each region for environmental projects. Mapping the participations of each region and the funding received provides insight into the regional distribution of Horizon Europe environmental projects.

3.2.2 Network analysis

The participation of multiple regions in each project within Horizon Europe creates a network in which nodes represent unique regions and the edges represent links between regions when they participate in the same project. A link between two regions is considered to be present when they participate in at least one project together (Meliciani et al. 2022). The regions that share more projects are considered to be more strongly linked, and the regions with a greater number of connections to others have a more central role in the network (Balland et al. 2019).

We constructed a network of participants in environmental projects represented by the $n \times n$ matrix $X=(x_{ij})$, where x_{ij} represents the number of connections between region i and region j. From the visualisation of this network, one can identify the most common connections between regions. Additionally, following the study by Balland et al. (2019), we calculated the degree centrality of each region, expressed as $\text{Degree}_i = \sum_j x_{i,j}$, to identify the number of direct connection of each node. We also calculated the eigenvector centrality, expressed as $\text{Eingen}_i = \sum_j X_{i,j} x_j$, which considers both the number of direct connections of the node, and the centrality of the node that it is connected to.

3.2.3 Regressions

We developed multiple linear mixed-effect models that aim to evaluate the participation of peripheral regions in environmental projects within Horizon Europe, as well as their funding and their centrality in the network of projects. Linear mixed-effect models are commonly used to deal with clustered data since the unobserved heterogeneity of clusters might cause intra-cluster correlation between data points (Peng and Lu 2012). In our analysis, data points are clusters and show within-group correlation around countries, making the linear mixed-effects model well-suited for capturing systematic influences (fixed effects) and unobservable variability (random effects) within these country groups. The three dependent variables allow to get a comprehensive picture of the quantity and quality (funding, centrality) of participation.

The first set of regressions uses the regional number of participations in environmental projects within Horizon Europe as the dependent variable. The second set of models uses the amount of funding received per region in euros as the dependent variable. The third set of models uses the eigenvector centrality measures of the region as the dependent variable. Robustness checks using degree centrality as the dependent variable yielded similar results. Ultimately, the selection of the eigenvector centrality measure over other centrality measures was based on its comprehensive consideration of the entire network structure. This measure not only assesses the centrality of individual nodes but also incorporates the propensity of a node to establish connections with other nodes that exhibit high centrality within the network (Balland et al. 2019).

A final set of models, Horizon Europe contributions, uses the regional funding received from the Horizon Europe programme as a whole as the dependent variable. This last model allows assessing whether the results for environmental projects reflect general patterns for all projects.

To construct the models, we included independent variables in a step-by-step procedure corresponding to the different concepts presented in Table 2, including geography, innovation, socio-economic and control variables. The independent variables are the same for the three sets of models focused on environmental projects. In the models focused on all projects, we only substituted the number of green patents with the total number of patents. Appendix I, contains a table that displays the correlations between these variables, and Appendix II contains the model formulas. Since the majority of the indicators are from EU sources, non-EU participants were eliminated from the dataset used for the regressions and missing values for individual regions were replaced with the national average when possible.

4 Results

4.1 Descriptive results

Figure 1 represents the amount of funding received by each region for environmental projects in comparison to their overall funding from Horizon Europe. Southern and Nordic regions often secure a larger amount of funding for environmental projects compared to the Horizon Europe programme as a whole. In contrast, Western regions tend to receive less funding for environmental projects compared to their overall participation in the programme. Eastern European regions receive relatively modest funding for both environmental projects and the programme as a whole.

When examining the funding that each region receives for environmental projects within Horizon Europe (Fig. 2), Île-de-France (FR10), the region that contains Paris, outperforms every other, with 110 million euros. However, Île-de-France receives a smaller share of funding for environmental projects compared to its overall funding received in the Horizon programme. The second region with the largest funding is Cataluña (ES51), region of Barcelona, in Spain, with nearly 66 million euros in environmental projects, and Lazio (ITI14), where Rome is located in Italy, with 59 million.

In terms of participation (Fig. 3), Île-de-France is the region with the highest number of participations, 220. This is followed by the Région de Bruxelles-Capitale (BE10), in Belgium, and Attiki (EL30), the region of Athens, in Greece, with 196 and 158 participations respectively. Both of these regions received comparatively more funding in environmental projects than in the rest of the programme. Figures 2 and 3 also show that regions located in Eastern Europe, the most northern part of the Nordics, the United Kingdom, and the regions surrounding Île-de-France are among the ones with the lowest levels of participations and funding in environmental projects.

The geographical distribution of Horizon Europe environmental projects show varying levels of participation and funding across different European regions. These

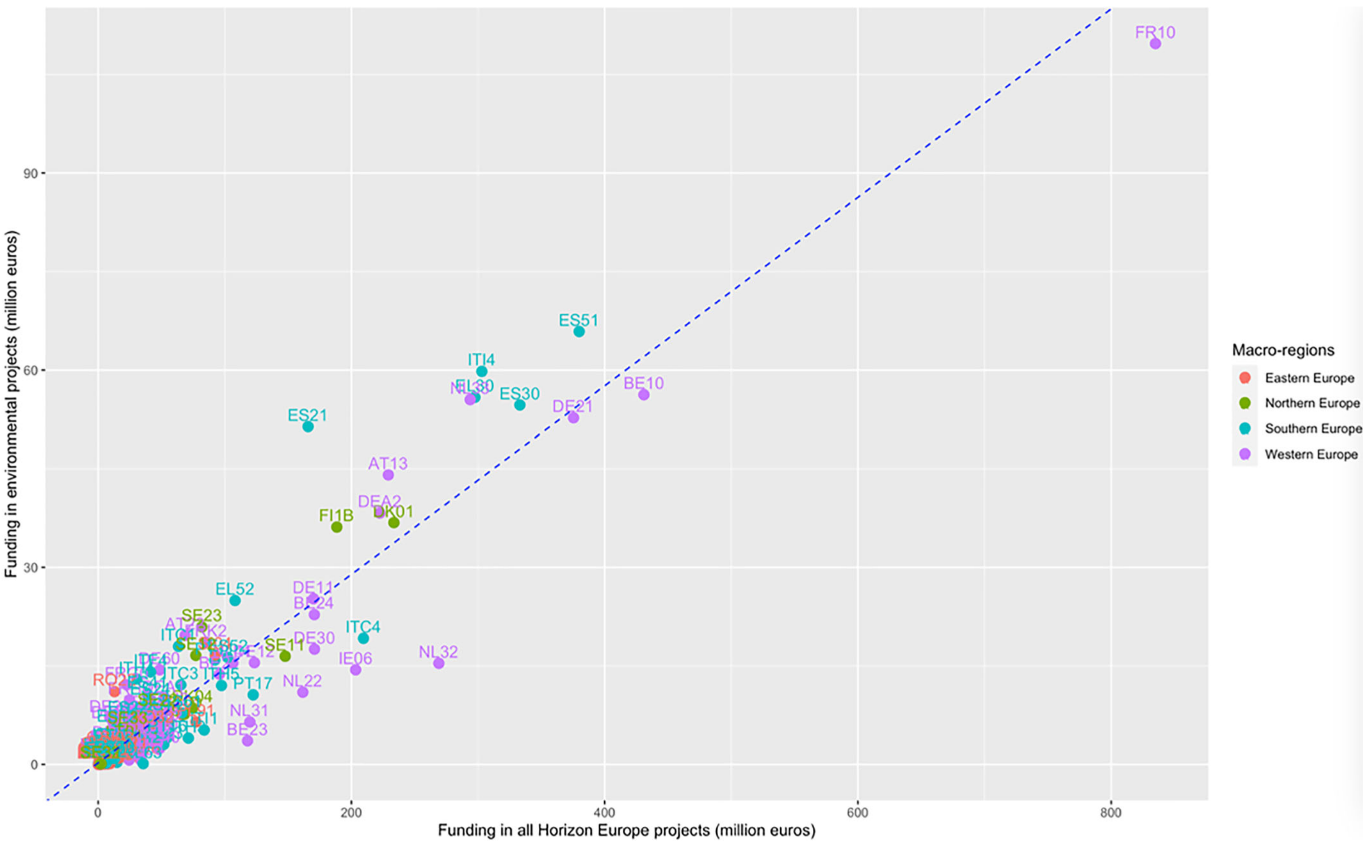

Fig. 1 Scatterplot of regional funding in all Horizon Europe projects vs. environmental projects by macro-region

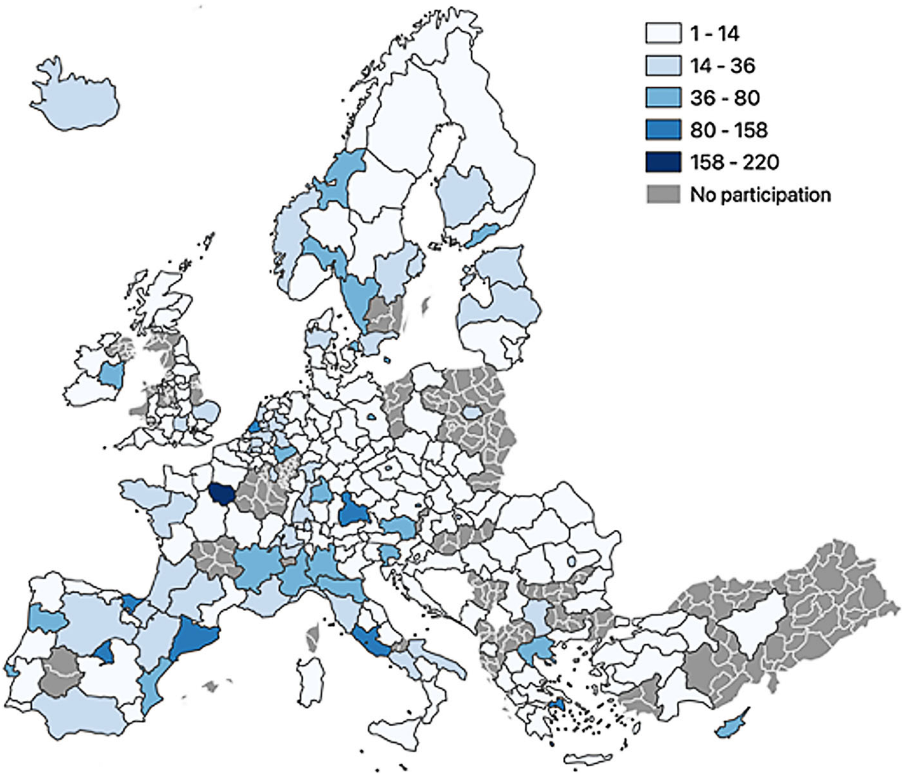

Fig. 2 Participation in Horizon Europe environmental projects per region

findings highlight the importance of examining the regional distribution of Horizon Europe projects, as a country-level perspective may overlook certain patterns. Additionally, analysing the dimensions of participation, and funding separately can provide a more comprehensive understanding of the impact of peripherality on the integration and cooperation environmental innovation projects in Horizon Europe.

4.2 Network analysis results

As discussed earlier, environmental innovation projects in Horizon Europe form a network of organisations across different regions collaborating together. In this network, the nodes represent each region, while the links represent collaboration in projects (Table. 3). The network of environmental projects in Horizon Europe as of December 2022 had a total of 296 projects in 263 regions. On average, each of the regions participates in 16.75 projects with Île-de-France participating in a maximum of 220 projects and multiple regions participating in just one. The degree centrality represents the number of connections from each region to another through a common project. The region with the maximum degree of centrality in the network is Bruxelles-Capitale, followed by Île-de-France and Comunidad de Madrid. The average degree centrality of the network is 65.16.

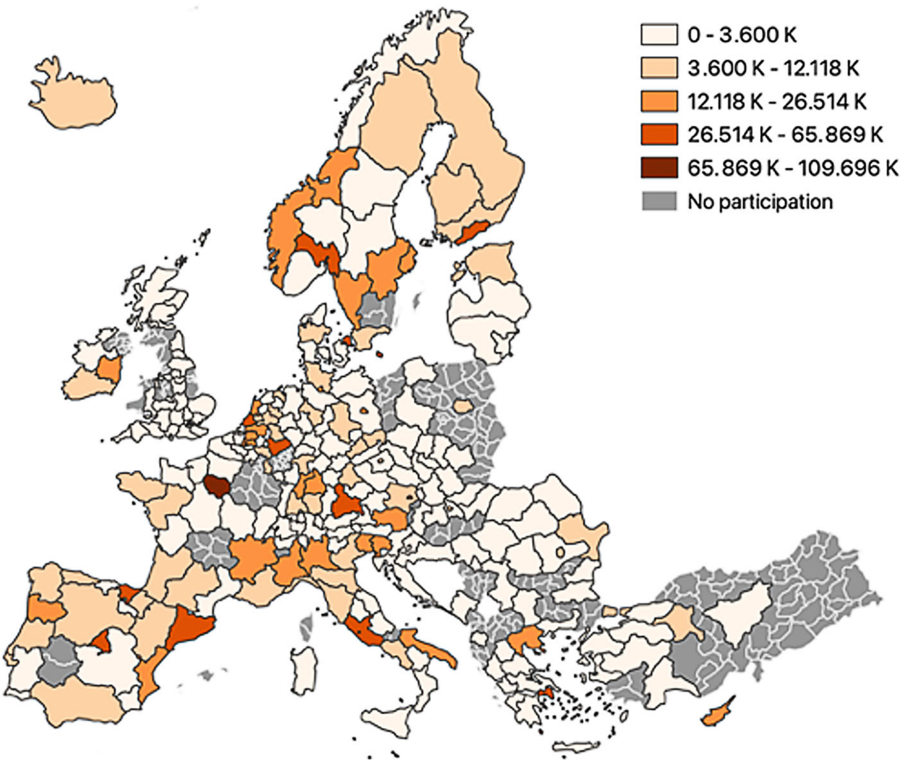

Fig. 3 Funding (in thousand EUR) in Horizon Europe environmental projects per region. (Classification in Figs. 2 and 3 based on the Jenks natural breaks optimisation method which clusters data to minimise each category's average deviation from the mean and make the best arrangement of values in different classes)

Figure 4 represents a network of the regions that have 20 or more linkages to others. The main connections are between the region of Île-de-France and Bruxelles-Capitale, Île-de-France and Zuid-Holland (region of The Hague), Bruxelles-Capitale and Zuid-Holland, Bruxelles-Capitale and Attiki, Bruxelles-Capitale and Lazio, and Attiki and Île-de-France. Figure 4 highlights the particularly busy connections between regions in the Netherlands, Belgium, and the north of France. The Nordics, on the other hand, exhibit three main connection hubs, namely Oslo og Viken, Hovedstaden (capital region of Copenhagen), and Helsinki-Uusimaa. Connectivity seems to decrease in Eastern European countries, where no single region shows a connection stronger than twenty projects with any other region. In comparison, Southern Europe is better connected: in Greece, Attiki shows the strongest connections to other regions, in Italy, Lazio shows the strongest connections, Spain is characterised by strong networks coming from Comunidad de Madrid, Cataluña and País Vasco, and Portugal shows strong connections coming from the Norte region and the Área Metropolitana de Lisboa (Lisboa Metropolitan Area). Overall, connections are particularly strong in capital regions, and in the Benelux area.

Table 3 Summary statistics of the Horizon Europe environmental projects network

Indicator	Network of projects
Number of projects	296
Number of regions	263
Mean project per region	16.75
Standard deviation	29.22
Minimum	1
Maximum	220
Average degree centrality	65.16
Standard deviation degree centrality	49.87
Minimum degree centrality	4
Maximum degree centrality	219

The network map in Fig. 4 and the maps in Figs. 2 and 3 already show some geographical patterns regarding peripherality and participation in Horizon Europe environmental projects. Regions in the northern part of the Nordics and Eastern Europe are more disconnected and participate less overall in environmental projects. Peripheral regions in Southern Europe, however, are better integrated into the network, as they have some of the strongest connections, as well as a number of regions with the highest participations in environmental projects. Moreover, capital regions, often the most innovative within a given country, show a more central role in the network of projects.

These results align with Calignano (2021), who discusses that relative innovativeness plays a larger importance than absolute innovativeness in determining centrality within EU innovation networks. Calignano (2021) further discussed that this might be due to the positive attitude of EU evaluators towards diversifying participation, and increasing the presence of peripheral regions in research and innovation programmes. This observation is also consistent with Balland (2012) findings, which showed that EU13 countries, mostly situated in Eastern Europe, have lower levels of participation in EU-FPs compared to other European countries.

4.3 Regression results

Table 4 shows the results of multiple linear models that examine the relationship between peripherality and the number of regional participations in Horizon Europe environmental projects. These models indicate a positive correlation between regions in Northern and Southern Europe and a higher number of participations in Horizon Europe environmental projects compared to Western regions. These models also suggest that more urban regions, with a higher population density, with a higher GERD, and higher human capital participate more in Horizon environmental projects, while the distance of the region from the national capital is not significant. Among the control variables, overall regional funding received from the Horizon Europe programme is highly significant in explaining the number of participations in environmental projects. Having a high level of regional environmental technology is also significant, to a lesser extent, in explaining participation.

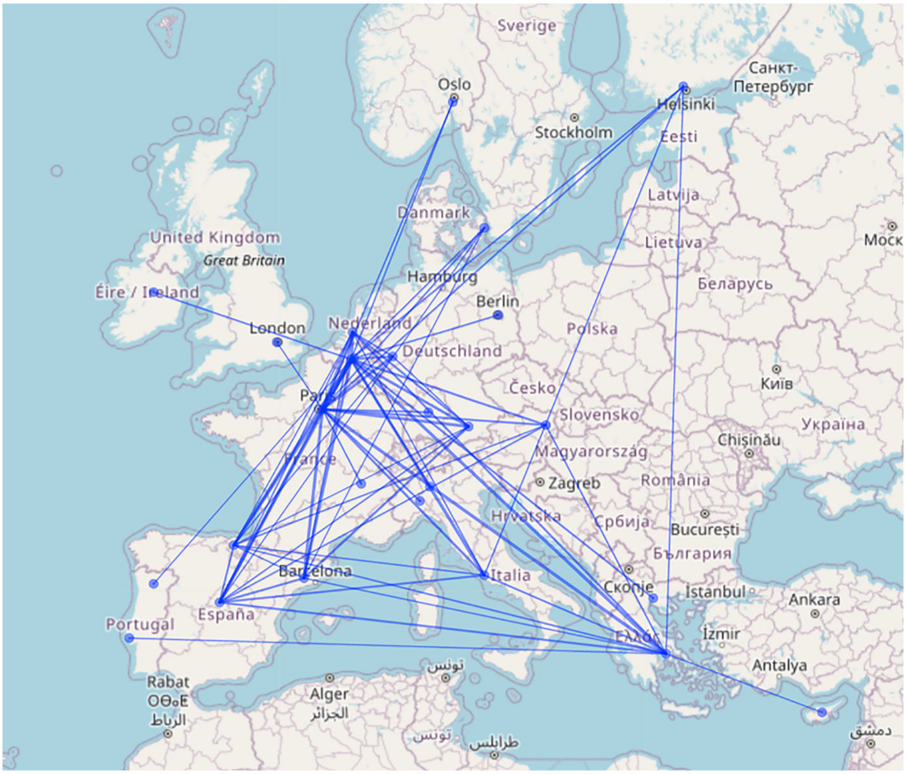

Fig. 4 Network of main collaborations (>19) in Horizon Europe environmental projects

Table 5 displays the results of the models examining the relationship between the logarithm of funding for environmental projects and various measures of peripherality. The results suggest a highly significant association between GERD and receiving higher funding. Regional human capital, population density and being located in Southern Europe are also associated, to a lesser extent, with receiving higher funding. It is also worth noting that in the geographic models (columns I.II and I.III) Eastern European regions show a weak negative association with funding received. Overall participation in the Horizon Europe programme has a positive relationship with funding in the participation, geography, innovation, and socio-economic models, but loses significance in the full model.

The regression analysis presented in Table 6 displays the outcomes for the models that take the regional eigenvector centrality in the network of projects as dependent variable. The results indicate that population density, human capital, regional GERD and a Northern European location are significantly positively associated with a larger centrality in the network. A Southern European locations also show a positive but weaker association with centrality, while unemployment shows a slight negative association with centrality. The distance to Bruxelles model (column I.I) suggests that regions further from Bruxelles and regions closer to the national capital city are associated with a greater centrality in the network, but this association is not

Table 4 Participation models, where the dependent variable is the number of participations (log)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical peripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
KM to Capital		–0.0366	–0.0164	–0.0210			–0.0003
		0.3081	0.6195	0.5633			0.9927
Population density (log)		0.5007***	0.4949***	0.5021***			0.4040***
		8.86E-09	8.60E-09	9.61E-09			4.17E-06
KM to Bruxelles		0.0337*		0.0061			0.0225
		0.0724		0.7781			0.2981
Eastern Europe			0.1847	0.1402			0.0573
			0.5310	0.6729			0.8696
Northern Europe			0.9254***	0.8801**			0.5670*
			0.0055	0.0176			0.0933
Southern Europe			0.7002**	0.6434*			0.7792**
			0.0183	0.0637			0.0226
RIS					–0.0007		–0.0039
					0.8353		0.3049
GERD (log)					0.7289***		0.4688***
					9.07E-10		4.06E-05
GDP per Capita						0.0135	–0.0058
						0.1667	0.5510
Human capital						0.0430***	0.0285***
						1.01E-05	0.0024
Unemployment						0.0203	–0.0237
						0.2644	0.2667
Horizon Europe	0.0094***	0.0061***	0.0062***	0.006***	0.0079***	0.0064***	0.0052***
	<2e-16	3.06E-09	6.69E-10	2.30E-09	<2e-16	2.98E-11	3.60E-08

Table 4 (Continued)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical peripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Env Tech	0.0016**	0.0025***	0.0021**	0.0022**	0.0009	0.0017**	0.0015*
	0.0461	0.0045	0.0116	0.0115	0.2472	0.0312	0.0638
Pollution	–0.0136	–0.0727**	–0.0499	–0.0502	0.0209	0.0178	–0.0426
	0.5542	0.0103	0.1378	0.1399	0.4774	0.4597	0.1880
Country dummies	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)
Constant	1.5210***	–0.3740	–0.6541	–0.7023	1.1420**	–0.8913*	–0.9471
	7.74E-07	0.4131	0.1522	0.1431	0.0399	0.0649	0.1810
N Regions	198	198	198	198	198	198	198
R2	0.5371	0.6219	0.6335	0.8653	0.8374	0.854	0.7119
Residuals Std. Error	0.9557	0.8647	0.8647	0.6355	0.6486	0.6381	0.7827

In the Macro-regions model (Column I.II) and the Full model (Column IV), the base level is set to Western Europe region at the threshold

* p = 0.05–0.1, ** p = 0.01–0.05, *** $p < 0.01$, P-values in parenthesis

Table 5 Intensity models, where the dependent variable is the amount of funding received for Horizon Europe environmental projects (log)

Variables	*(0)	(I.I)	(I.II)	(I.III)	(II)	(III)	(IV)
	Control	Distance to Bruxelles	Macro-Regions	Geographical peripherality	Innovation peripherality	Socio-economic peripherality	Full model
KM to Capital		–0.0089	–0.0172	–0.0258			0.0404
		0.9351	0.8650	0.8142			0.7031
Population density (log)		0.7429***	0.6869***	0.7019***			0.4420*
		0.0041	0.0045	0.0056			0.0914
KM to Bruxelles		0.0471		0.0119			0.0844
		0.3602		0.8374			0.1688
Eastern Europe			–1.3843*	–1.4574*			–1.1630
			0.0719	0.0864			0.2306
Northern Europe			1.3716*	1.2912			0.1837
			0.0839	0.1453			0.8359
Southern Europe			0.9661	0.8729			1.4750*
			0.1086	0.2475			0.0503
RIS					0.0076		0.0086
					0.4387		0.4714
GERD (log)					1.2657***		1.0660***
					0.0001		0.0016
GDP per Capita						0.0313	–0.0005
						0.2809	0.9872
Human capital						0.0957***	0.0581**
						0.0006	0.0122
Unemployment						0.0699	–0.0629
						0.1879	0.3251
Horizon Europe	0.0121***	0.008***	0.0073**	0.0072**	0.0100***	0.00545**	0.0044
	2.55E-06	0.0084	0.0102	0.0135	6.24E-05	0.0496	0.1322

Table 5 (Continued)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical peripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Env Tech	–0.1279*	0.003	0.0023	0.0025	–0.0001	0.0028	0.0092
	0.0654	0.2455	0.3224	0.3139	0.9555	0.2265	0.7140
Pollution	0.0027	–0.2202***	–0.0768	–0.0789	–0.0384	–0.0607	–0.0035
	0.2464	0.0062	0.4129	0.4044	0.6341	0.3881	0.9706
Country dummies	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)
Constant	14.7771***	11.9010***	11.0307***	10.9339***	12.9626***	9.2144***	7.7650***
	2.00E-16	6.36E-15	1.84E-14	5.78E-13	2.01E-13	2.43E-09	0.0005
N Regions	198	198	198	198	198	198	198
R2	0.2548	0.2912	0.2987	0.2989	0.3362	0.3469	0.3947
Residuals Std. Error	2.772	2.7283	2.716	2.723	2.631	2.603	2.565

In the Macro-regions model (Column I.II) and the Full model (Column IV), the base level is set to Western Europe region at the threshold

* p = 0.05–0.1, ** p = 0.01–0.05, *** $p < 0.01$, P-values in parenthesis

Table 6 Eigenvector centrality models, where the dependent variable is the eigenvector centrality measure

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical peripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Population density (log)		0.4944***	0.4959***	0.5030***			0.4223***
		1.49E-08	6.28E-09	8.68E-09			1.24E-06
KM to Capital		0.0658*	–0.0413	–0.0451			–0.0304
		0.0679	0.2141	0.2150			0.3672
KM to Bruxelles		0.0385**		0.0045			0.0185
		0.0300		0.8235			0.3621
Eastern Europe			0.3863	0.3529			0.0814
			0.1567	0.2492			0.8003
Northern Europe			0.9101***	0.8782***			0.6233**
			0.0022	0.0088			0.0425
Southern Europe			0.7647***	0.7238**			0.8625***
			0.0038	0.0211			0.0058
RIS					–0.0019		–0.0067*
					0.5790		0.0814
GERD (log)					6.2990***		0.3489***
					1.66E-07		0.0015
GDP per Capita						0.0127	–0.0038
						0.1942	0.6932
Human capital						0.0454***	0.0314***
						4.02E-06	0.0005
Unemployment						0.0058	–0.0389*
						0.7508	0.0617
Horizon Europe	0.0087***	0.0052***	0.0053***	0.0053***	0.0075***	0.0057***	0.0043***
	<2e-16	2.72E-07	5.68E-08	1.62E-07	3.67E-16	3.07E-09	7.23E-06

Table 6 (Continued)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical peripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Env Tech	0.0014***	0.0025**	0.0021***	0.0022***	0.0009	0.0015*	0.0018**
	0.0672	0.0039	0.0084	0.0087	0.2760	0.0598	0.0253
Pollution	–0.0212	–0.0868***	–0.0761**	–0.0764**	–0.0007	0.0099	–0.0705**
	0.3362	0.0015	0.0194	0.0204	0.9980	0.6805	0.0255
Country dummies	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)
Constant	3.291***	–5.076***	–5.289***	–5.332***	3.401***	–5.655***	–5.329***
	<2e-16	<2e-16	<2e-16	<2e-16	1.12E-08	<2e-16	3.12E-12
N Regions	198	198	198	198	198	198	198
R2	0.4828	0.5770	0.5883	0.5902	0.5793	0.6034	0.6678
Residuals Std. Error	0.9718	0.8815	0.8799	0.8807	0.8828	0.8589	0.8038

In the Macro-regions model (Column I.II) and the Full model (Column IV), the base level is set to Western Europe region at the threshold

* p = 0.05–0.1, ** p = 0.01–0.05, *** $p < 0.01$, P-values in parenthesis

significant in other models. Regarding the control variables, overall funding from Horizon Europe, and regional environmental technology are positively associated with higher eigenvector centrality, while pollution is negatively associated with centrality.

Finally, Table 7 reports estimates for the relationship between overall funding received from the Horizon Europe programme and various measures of peripherality. The results suggest a highly significant positive association between a larger distance from Bruxelles and regional GERD with receiving higher funding. Proximity to the national capital, population density, and human capital also indicate a weak positive association with funding in Horizon Europe. On the contrary, a Northern European location is associated with receiving lower funding in Horizon Europe. A higher patent intensity is associated with higher funding in all models, while higher pollution is associated with higher funding in the innovation and socio-economic models.

5 Conclusions

Our aim in this study was to provide novel empirical evidence on the idea of green windows of opportunity for peripheral regions using data about environmental projects funded by Horizon Europe. Overall, our results suggest that the programme does indeed provide a window of opportunity for peripheral regions, however, this window is not uniform across the continent. The integration into environmental projects is substantially better in Northern and Southern European regions compared to Western Europe and in capital regions with high population density. Meanwhile, Eastern European regions tend to be less integrated into environmental projects than other regions, indicating that they may not benefit as much from the green windows of opportunity emerging from Horizon Europe.

We investigated the role of different dimensions of peripherality and we demonstrated how each dimension tells a specific story. On one hand, geographical peripherality is not the only dimension that matters. Innovation and economic definitions also capture key dimensions of peripherality. Our results consistently aligned with a negative relationship between both innovation and socio-economic peripherality, and the integration of regions in Horizon Europe environmental projects. On the other hand, even geographical peripherality has different elements to it. The analysis of the inclusion of peripheral regions in networks of environmental innovation in Horizon Europe reveals that, when examining Europe as a whole, peripheral regions are better connected. When considering relative, within-country, peripherality, our findings revealed that being further away from the capital city and having a more dispersed population had a negative relationship with centrality in Horizon Europe environmental projects. These results underscore the importance of examining absolute and relative levels of geographical peripherality separately, to uncover distinct patterns.

It was also worth distinguishing between the general innovation opportunities afforded by Horizon Europe and the specific opportunities presented by its green agenda. The results indicate that regions with higher overall participation in Horizon

Table 7 Horizon Europe model, where the dependent variable is the regional funding received from the Horizon Europe programme (log)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical pe-ripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Population density (log)		0.0003*	0.3239*	0.4357***			0.3150**
		0.0678	0.0515	0.0047			0.0645
KM to Capital		–0.1763***	–0.0585	–0.1833***			–0.1123*
		0.007	0.3597	0.0043			0.0804
KM to Bruxelles		0.1635***		0.1805***			0.1517***
		7.34E-06		5.63E-07			0.0001
Eastern Europe			0.1424	0.0709			0.2689
			0.6735	0.8278			0.3987
Northern Europe			–0.7832	–0.979**			–0.821*
			0.1176	0.0457			0.0806
Southern Europe			0.3779	0.1289			0.2086
			0.2519	0.6855			0.4988
RIS					–0.0027		0.0004
					0.717		0.9518
GERD (log)					1.1613***		0.6988***
					1.11E-05		0.0046
GDP per Capita						–0.0060	–0.0091
						0.7573	0.6460
Human capital						0.0621***	0.0388**
						0.0011	0.0310
Unemployment						0.1108***	0.0486
						0.0031	0.1708
Patent applications (log)	0.9571***	1.025***	0.8794***	0.9675***	0.6854***	0.8489***	0.7457***
	<2e-16	<2e-16	<2e-16	<2e-16	2.13E-09	6.06E-16	1.01E-09

Table 7 (Continued)

Variables	*(0) Control	(I.I) Distance to Bruxelles	(I.II) Macro-Regions	(I.III) Geographical pe-ripherality	(II) Innovation peripherality	(III) Socio-economic peripherality	(IV) Full model
Pollution	0.1284**	0.0626	0.0736	0.0108	0.1194**	0.1282***	0.0499
	0.016	0.1777	0.2141	0.8248	0.042	0.0087	0.40409
Country dummies	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)	Yes (23)
Constant	11.2921***	10.3700***	10.7014***	9.0110***	12.3979***	8.6488***	8.2630***
	<2e-16	<2e-16	<2e-16	<2e-16	<2e-16	<2e-16	2.46E-09
N Regions	229	229	229	229	229	229	229
R2	0.4449	0.4956	0.4719	0.5068	0.5128	0.5051	0.5597
Residuals Std. Error	1.8640	1.8143	1.8354	1.8036	1.7690	1.8017	1.7312

In the Macro-regions model (Column I.II) and the Full model (Column IV), the base level is set to Western Europe region at the threshold

* p = 0.05–0.1, ** p = 0.01–0.05, *** $p < 0.01$, P-values in parenthesis

Europe also tend to have greater involvement in green projects. However, this pattern still leaves space for some regions to exhibit stronger engagement in environmental projects than in Horizon Europe overall. The analysis revealed that certain Northern and Southern regions are more actively engaged in environmental projects under Horizon Europe than in the broader research programme. This suggests that Horizon Europe is creating a unique window of opportunity for these regions to advance their environmental innovation efforts. Conversely, Western and Eastern European regions tend to participate less in environmental projects than in other thematic priorities of Horizon Europe. While absolute distance to Bruxelles and proximity to the national capital are highly relevant at explaining overall funding in Horizon Europe, macro-regions are more relevant at explaining the distribution of environmental projects.

In addition, as could be expected, regions that have invested in developing and implementing advanced green technologies are better integrated into environmental projects. This may be due to several factors, such as greater awareness of environmental issues, larger access to resources and knowledge related to environmental innovation, and a commitment to sustainability. The relationship between green technology and integration in environmental projects implies that regions with advanced environmental technology are better positioned to benefit from green windows of opportunity. Considering these findings, promoting the development of environmental technology could be a crucial strategy to encourage participation in environmental innovation projects.

It is also worth noting that several Eastern European regions have relatively high levels of pollution and low environmental technology (European Environment Agency 2022; Perruchas et al. 2020), which raises questions about how to integrate these regions more effectively into green initiatives. Further research could explore the reasons for their lack of participation, such as whether they submit fewer applications for Horizon Europe environmental projects, if their applications are not being selected, or if they lack awareness or capacity to participate in environmental projects. Understanding the factors behind the lack of integration of peripheral regions in Eastern Europe could inform the development of new support programmes. Examples could include creating centres to facilitate the submission of applications for environmental projects, offering support to the existing green industries to develop higher capacities, or creating dedicated platforms to encourage the creation of networks in these regions.

This study is not without limitations. We exclusively focused on the distribution of projects, rather than delving into the specific roles of participants or their relative inputs to the projects. These perspectives would be particularly interesting in further research that engages in assessing the actual outcomes of regional participation in the programme. Such research could investigate the different participants' roles within projects in core and peripheral regions, and explore the ability of regions to deliver effective results after the project allocation. Clearly those investigations will be most informative and meaningful when carried out once the Horizon programme comes to an end, after 2027. Our analysis has included several dimensions of regional participation (from the number of projects to the quality of participation in terms of network centrality and actual funding received), but has treated them independently. Future research could investigate how these different dimensions play a role for the impact of Horizon Europe. For instance: do fewer projects with more funding matter more for regions than more projects with less funding but more collaborations? Trade-offs might be at play, given constraints to participate in many projects at the same time.

Horizon Europe was designed to support scientific excellence in the direction of the European Green Agenda. Our findings stress that participation in environmental projects has so far not been uniform across the continent and has concentrated in a few places. Peripheral regions often face unique barriers to innovation, such as weaker connectivity and lower levels of human capital. As a result, the effectiveness of research and innovation programmes such as Horizon Europe may vary depending on the regional context. This resonates with scholarly work that has warned that a "one-size-fits-all" policy for environmental innovation might not be enough (Tödtling and Trippl 2005). Targeted interventions and policies may be necessary to support green transitions in peripheral regions and to ensure that they are not left behind in the pursuit of sustainable development. Without addressing these issues, the externalities of environmental degradation and the impact of the transformation of jobs during the green transition may be disproportionately borne by peripheral regions (OECD 2023), while others reap the new green windows of opportunity.

6 Appendix

6.1 Appendix I

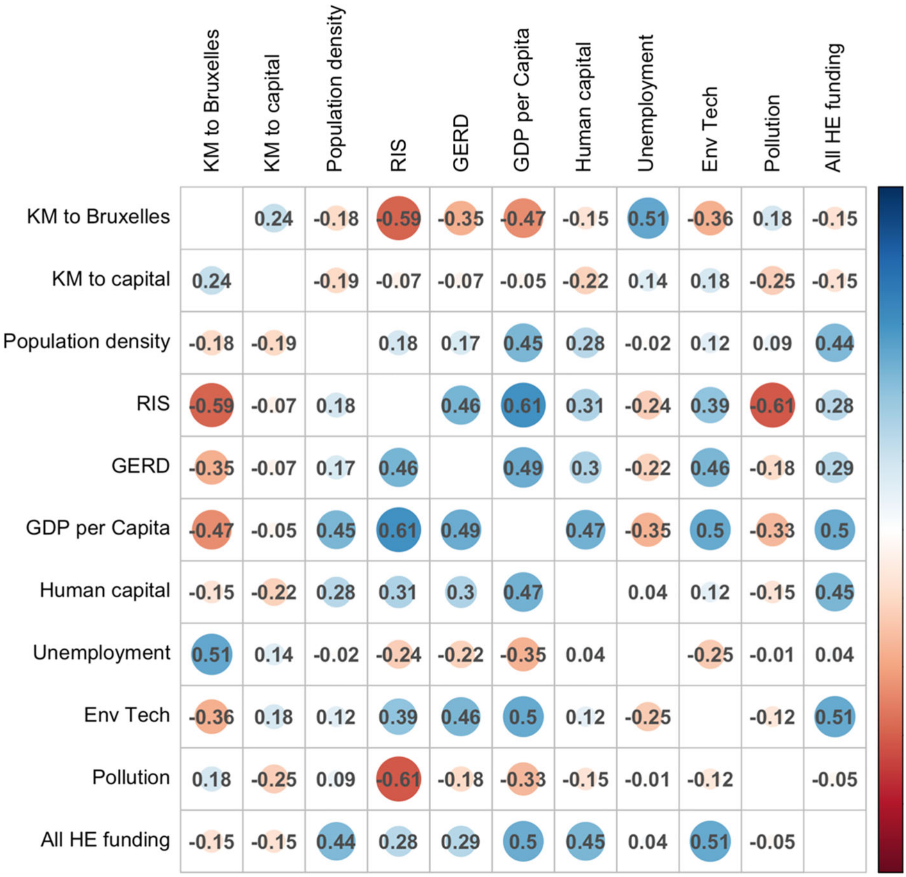

Fig. 5 Correlation table of key variables

6.2 Appendix II: Model formulas

A. Participation models

- (0) Control: *Green project participation* ~ *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.I) Distance to Bruxelles: *Green project participation* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.II) Macro-regions: *Green project participation* ~ *log (population density)* + *KM to capital* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.III) Geographical peripherality: *Green project participation* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (II) Innovation peripherality: *Green project participation* ~ *RIS* + *log (GERD)* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (III) Socio-economic peripherality: *Green project participation* ~ *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (IV) Full model: *Green project participation* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *RIS* + *log (GERD)* + *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)

B. Intensity models

- (0) Control: *log(Green project contributions)* ~ *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.I) Distance to Bruxelles: *log(Green project contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.II) Macro-regions: *log(Green project contributions)* ~ *log (population density)* + *KM to capital* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.III) Geographical peripherality: *log(Green project contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (II) Innovation peripherality: : *log(Green project contributions)* ~ *RIS* + *log (GERD)* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (III) Socio-economic peripherality: *log(Green project contributions)* ~ *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (IV) Full model: *log(Green Project contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *RIS* + *log (GERD)* + *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)

C. Eigenvector centrality models

- (0) Control: *Eigenvector centrality* ~ *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.I) Distance to Bruxelles: *Eigenvector centrality* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.II) Macro-regions: *Eigenvector centrality* ~ *log (population density)* + *KM to capital* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (I.III) Geographical peripherality: *Eigenvector centrality* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Macro-regions* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (II) Innovation peripherality: *Eigenvector centrality* ~ *RIS* + *log (GERD)* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (III) Socio-economic peripherality: *Eigenvector centrality* ~ *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)
- (IV) Full model: *Eigenvector centrality* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *RIS* + *log (GERD)* + *GDP per capita* + *Human capital* + *Unemployment* + *Env Tech* + *Pollution* + *All HE Funding* + (1| *Country*)

D. Horizon Europe funding models

- (0) Control: *log (Horizon Europe contributions)* ~ *Patents* + *Pollution* + (1| *Country*)
- (I.I) Distance to Bruxelles: *log(Horizon Europe contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Patents* + *Pollution* + (1| *Country*)
- (I.II) Macro-regions: *log (Horizon Europe contributions)* ~ *log (population density)* + *KM to capital* + *Macro-regions* + *Patents* + *Pollution* + (1| *Country*)
- (I.III) Geographical peripherality: *log (Horizon Europe contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *Macro-regions* + *Patents* + *Pollution* + (1| *Country*)
- (II) Innovation peripherality:: *log (Horizon Europe contributions)* ~ *RIS* + *log (GERD)* + *Patents* + *Pollution* + (1| *Country*)
- (III) Socio-economic peripherality: *log (Horizon Europe contributions)* ~ *GDP per capita* + *Human capital* + *Unemployment* + *Patents* + *Pollution* + (1| *Country*)
- (IV) Full model: *log (Horizon Europe contributions)* ~ *log (population density)* + *KM to capital* + *KM to Bruxelles* + *RIS* + *log (GERD)* + *GDP per capita* + *Human capital* + *Unemployment* + *Patents* + *Pollution* + (1| *Country*)

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