Mapping Circular Innovation: A Regional Analysis of Technological progress in the Circular Economy

(Extended Abstract)

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Introduction

The economic, financial, health and geopolitical crises of the last two decades have had a significant impact on global socio-economic conditions, widening inequalities and adversely affecting territories. In this context, the continuous growth of the world's population, accompanied by an ever-increasing demand for goods, has led to an excessive demand for raw materials and energy (Ellen Macarthur Foundation, 2013) leading the main international organizations and institutions to rethink the sustainability of the linear model (Korhonen et al., 2018) promoting policy instruments and medium to long-term projects toward a system that pursues a more balanced economic development, environmental sustainability and social inclusion. Among the possible solutions identified, the circular economy represents the most suitable strategy promoting the development of a closed-loop system where resources are reused and reintegrated into the production cycle, thereby reducing the demand for new raw material, reducing the waste and extending the lifespan of materials and products.

In the context of circular transition, for it to happen and for international strategies to work, the role of innovation in driving all changes, be they technological, systemic or business model, becomes central (Jakobsen et al., 2021; Portillo-Tarragona et al., 2024; Prieto-Sandoval et al., 2018; Suchek et al., 2021). Indeed, it is well established in the literature that the capacity of territories to innovate is essential for adapting to structural change, in addition to sustaining long-term economic growth (Bachtrögler-Unger et al., 2023; Balland & Rigby, 2017). However, this innovative potential is unevenly distributed across space and depends on the nature and structure of local capabilities. In this context, the concept of technological complexity has emerged as a useful way of understanding the sophistication and diversity of regional knowledge bases and explaining why some regions are better positioned to generate advanced, cross-sectoral innovations (Balland & Rigby, 2017; Broekel, 2018). This is particularly relevant for the circular economy (CE), which involves the integration of diverse knowledge domains (Caldarola et al., 2024). Recent work has shown that regions with higher technological complexity are not only more likely to diversify into emerging and sustainable technologies but are also better prepared to seize opportunities arising from the twin transition (Bachtrögler-Unger et al., 2023). In addition to complexity, a region's relatedness, which captures how closely different activities are linked in terms of required knowledge and capabilities, also plays a key role in shaping its diversification pathways (R. Boschma, 2017; R. A. Boschma, 2005; Hidalgo et al., 2018). Research has shown that regions tend to expand into new technological domains that are closely related to their existing strengths, and this principle has been widely applied to understand green and digital innovation trajectories (Bachtrögler-Unger et al., 2023; Balland et al., 2019). The circular economy can thus be interpreted as an operational dimension of the green transition, where the ability to innovate depends not only on the complexity but also on the alignment of regional capabilities with circular innovation domains.

However, despite its importance, the link between the circular economy and innovation is underexplored, with existing studies often focusing on specific technologies or individual innovations, and it is therefore important to deepen its role (Chizaryfard et al., 2021; Herrero-Luna et al., 2022). At the same time, the role of technological complexity has been subject to increased examination in relation to green and digital transitions, while its specific influence on the development of circular economy innovation remains largely poor and fragmented (Cainelli et al., 2020; Capello & Conte, 2023; de Jesus et al., 2016; Fusillo et al., 2023).

The aim of this paper is therefore to investigate the territorial dynamics and key enablers of circular innovation at the European regional (NUTS2) level, with a specific focus on the role of technological complexity. The study aims to address the research gap by examining whether and how technological complexity contributes to the development of CE innovation across space. To this end, innovation output is approximated by patents in the circular domain, a metric frequently employed in extant literature as it reflects invention, provides substantial information on the residence of inventors and applicants and is available over extended periods (Breschi & Lissoni, 2004; Fusillo et al., 2023; Griliches, 1998; Marrocu et al., 2013; Usai, 2011).

Methodology

Circular patent data will be obtained using the PATSTAT and REGPAT databases. The method that will be used to carry out this search is a new automatic landscaping approach (Ghinami et al, forthcoming) based on the methods of Abood & Feltenberger (2018) and Jindra & Leusin (2022) that consists of three main operations:

• An automatic selection, innovative aspect aimed at reducing any kind of bias derived from the human activities and making it more replicable, of the most representative patents (seed) using CPC codes (Y02W) and keywords used in the literature.

• An expansion of the seed to include a level of innovation not considered by the two previous categories, and therefore a frontier.

• A machine learning pruning approach to refine the results and the final selection.

Once the data on patents have been collected, they will be geolocalised at NUTS2 level, using the information accompanying the patents, for European regions, along time and across sectors.

This methodology is designed to ensure a comprehensive identification of patents related to circular economy technologies and practices. These data, then, will be used as dependent variable in a subsequent econometric study. The aim of this study will be to analyze the determinants that most influence these innovation dynamics. This analysis will be undertaken within the usual Knowledge Production Function (KPF) framework. A further objective is to make comparisons between results in different regions and time periods, and to evaluate the presence of local externalities of various forms (Usai, 2011).

The main explanatory variables are the technological complexity index, which will be constructed following the methodologies developed by Balland & Rigby (2017) and Broekel (2018), and the average relatedness density to the CE domain. The utilization of the complexity index will facilitate an assessment of whether regions characterized by a complex knowledge base are structurally better equipped to generate innovations of a circular nature. The model will also account for knowledge flows across regions, as these are known to play a crucial role in shaping innovation outcomes (Moreno et al., 2005; Paci & Usai, 1999, 2009; Quatraro & Usai, 2017).

Expected Contribution and Conclusion

Through the analysis of circular patents, this study will try to provide new insights into the mapping of circular innovations across European regions, providing new empirical evidence on which elements most determine the dynamics of the diffusion of technological progress and knowledge flows at the regional NUTS2 level. In particular, the analysis seeks to understand how technological complexity and relatedness to CE domain, as structural characteristics of regional knowledge bases, influence the capacity of regions to engage in CE innovation.

In addition to identifying these structural drivers, the study incorporates a spatial analytical framework to account for potential spillover effects across regions. By explicitly modeling spatial dependence, the analysis controls for the possibility that innovation dynamics in the CE domain are influenced not only by internal regional capabilities but also by knowledge diffusion, interregional linkages, and geographical proximity. This spatial perspective allows for a more comprehensive understanding of how circular innovations spread across the European territory and whether regional innovation performance is shaped by neighboring regions' technological structures and specialization patterns.

The findings of this study are expected to contribute to the growing body of literature on circular economy and innovation systems, while providing policy makers with valuable insights to inform the development of policies and initiatives aimed at promoting the circular economy and innovation across various regions. These insights will consider regional capabilities and complexities, with the intention of supporting a more inclusive and effective circular transition throughout the European Union.

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