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Innovation, technology and sustainable transition: Insights from Italian SMEs

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Innovation, technology and sustainable transition: Insights from Italian SMEs

Massimiliano Mazzanti¹ Alessandro Montanaro² Fabiola Onofrio³ Emy Zecca⁴

Abstract

This work investigates sustainability-oriented innovation among Italian small and medium-sized enterprises (SMEs) within the broader context of the European twin transition toward sustainability and digitalization. Based on survey data from 740 manufacturing firms, it analyses the diffusion of research and development activities, digital technologies, and circular economy practices across firm sizes and regions. The results reveal a persistent dualism: medium and large firms, mostly located in northern regions, show higher levels of innovation and digital adoption, while smaller firms remain limited by financial and structural constraints. Circular innovation largely focuses on efficiency measures, whereas advanced strategies such as eco-design remain rare. Digitalization acts as both a driver and an enabler of sustainable transformation but progresses unevenly across territories.

1. Introduction

The transition towards sustainability has evolved from a normative aspiration into a strategic and systemic transformation that redefines the foundations of production, consumption, and governance in contemporary economies. Increasing environmental degradation, resource scarcity, and climate instability have exposed the ecological limits of the linear and growth-driven economic paradigm, revealing the necessity of new development models that combine economic prosperity, social inclusion, and ecological integrity (Rockström et al., 2009; Sachs et al., 2019). Within this context, sustainability is no longer conceived as a peripheral or ethical concern but as a core organising principle for innovation, competitiveness, and long-term resilience.

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At the European level, this reorientation has been formalised through the European Green Deal and its accompanying policy architecture, which position sustainability at the heart of industrial policy, research funding, and digital transformation strategies (European Commission, 2019). The shift towards a climate-neutral, resource-efficient, and socially just economy requires not only technological upgrading but also a profound restructuring of institutional frameworks, market incentives, and social practices. In this perspective, sustainability transitions are understood as multi-level, multi-actor processes involving the co-evolution of technological, organisational, and cultural change (Geels, 2002; Markard et al., 2012).

Among the various pathways towards sustainability, the Circular Economy (CE) represents a crucial but not exhaustive component. While circularity focuses on resource regeneration, waste valorisation, and closed-loop systems, the broader sustainability transition encompasses a wider range of domains—such as energy decarbonisation, biodiversity preservation, social innovation, and equitable development—all interconnected within a systems-based understanding of change (Kirchherr et al., 2018; Kemp & Pearson, 2007). The CE thus constitutes one operational pillar within a more comprehensive green transformation agenda, which includes green innovation, digitalisation, and institutional coordination as complementary drivers of systemic change.

In this evolving landscape, green innovation has emerged as a critical lever for aligning economic growth with environmental protection. Defined as the development and diffusion of products, processes, and organisational methods that reduce environmental harm, enhance resource efficiency, and support climate mitigation (Horbach, 2016), green innovation enables firms to internalise environmental objectives within their competitive strategies. Empirical evidence shows that firms engaging in green innovation are more resilient, export-oriented, and better positioned to comply with evolving regulatory and market demands (Cainelli & Mazzanti, 2013; Ghisetti & Rennings, 2014). However, the diffusion of green innovation depends strongly on contextual factors, including access to finance, regulatory stability, knowledge networks, and consumer awareness.

Parallel to these environmental transformations, the digital transition—often framed together with sustainability as the twin transition—is reshaping the technological and organisational foundations of production systems. Digital tools such as artificial intelligence (AI), Internet of Things (IoT), blockchain, and data analytics enable unprecedented levels of efficiency, transparency, and traceability along global value chains. These technologies support smart manufacturing, predictive maintenance, resource monitoring, and supply chain optimisation, thereby reinforcing both environmental and economic performance (OECD, 2023; European Investment Bank, 2022). The synergy between green and digital innovation generates a self-reinforcing dynamic: digitalisation enhances the precision and effectiveness of environmental management, while sustainability imperatives stimulate the development of new digital solutions for decarbonisation, waste reduction, and social inclusion.

At the national level, Italy's sustainability transition embodies both opportunities and challenges. The country's productive fabric is dominated by Small and Medium-sized Enterprises (SMEs), which account for

roughly 99% of all firms, 80% of private-sector employment, and over 70% of national value added (European Commission, 2023). These firms represent the backbone of the Italian economy, embedded in dense industrial districts and characterised by strong territorial clustering, craft-based know-how, and incremental innovation capabilities. Historically, such features have fostered material efficiency and adaptive learning, aligning traditional practices with sustainability principles long before these became policy imperatives (Mazzanti & Zoboli, 2009).

Recognising these asymmetries, Italy's National Recovery and Resilience Plan (PNRR)—developed within the framework of Next Generation EU—has prioritised sustainability and digitalisation as mutually reinforcing pillars of national recovery. The PNRR allocates significant investments to energy efficiency, renewable energy deployment, sustainable mobility, circular economy infrastructures, and digital capacity-building for SMEs (Ministero dell'Economia e delle Finanze, 2021). Complementary initiatives, such as Transizione 4.0, regional Smart Specialisation Strategies (S3), and various cluster-based innovation programmes, aim to enhance the diffusion of green technologies, digital tools, and innovation networks across the country. These policies underscore the need for integrated approaches that address not only technological upgrading but also skills development, institutional coordination, and social inclusion, ensuring that the transition remains both just and competitive.

From a theoretical standpoint, the sustainability transition framework integrates insights from innovation systems theory, transition studies, and ecological economics, emphasising the interdependence between technological innovation, institutional change, and societal transformation (Markard et al., 2012; Kemp & Pearson, 2007). Within this framework, SMEs act as critical nodes in multi-level innovation systems: they are simultaneously constrained by systemic barriers—limited access to capital, skills, and networks—and empowered by their flexibility, local embeddedness, and proximity to consumers. Their collective transformation, therefore, represents not only an industrial challenge but also a societal opportunity for inclusive and regionally balanced growth.

Against this backdrop, the present report seeks to examine the extent, patterns, and determinants of sustainability-oriented innovation among Italian SMEs, situating their experiences within the broader European twin-transition context. It aims to map the current landscape of sustainable transformation, assess the interactions between green and digital innovation, and identify both the structural enablers and institutional bottlenecks shaping these dynamics. The data used in this analysis were obtained within the framework of the cascade funding call TINKER⁵, part of the PNRR project GRINS⁶. By adopting a systemic and comparative approach, the analysis contributes to a deeper understanding of how SMEs—despite their heterogeneity—can

⁵ TINKER - Territories, Innovations, and Knowledge for Circular Economy Research

⁶ GRINS – Growing Resilient, Inclusive and Sustainable (PNRR, Missione 4, Componente 2, Investimento 1.3) <https://grins.it/>

act as agents of systemic sustainability transformation, supporting the emergence of a more resilient, inclusive, and low-carbon economy. Ultimately, the report aspires to inform evidence-based policy design, fostering multi-scalar strategies that align technological innovation, environmental stewardship, and social equity in the pursuit of long-term sustainability.

2. Conceptual framework

The conceptual framework guiding this work is rooted in a systems-based understanding of innovation, which conceives of technological, organizational, and social change as the outcome of complex, multi-level interactions among firms, industries, institutions, and policy regimes. This approach rejects the notion of innovation as a purely firm-level or linear process and instead emphasises the interdependence of actors and the co-evolution of technologies, markets, and governance structures (Kemp & Pearson, 2007; Geels, 2002). Drawing simultaneously on Eco-Innovation Theory and the Multi-Level Perspective (MLP) on socio-technical transitions, the framework elucidates how sustainability-oriented innovations emerge, diffuse, and become stabilised within broader economic and institutional regimes. These theories together offer a lens through which innovation can be understood as embedded within layered systems—ranging from niche-level experiments to established industrial regimes and overarching landscape pressures such as globalisation, climate change, or shifts in consumer norms (Geels, 2011).

Within the Italian context, such a perspective necessitates an appreciation of territorially embedded innovation capabilities, where regional production systems, industrial districts, and sectoral clusters play a decisive role in mediating the diffusion of eco-innovations. Italy's long-standing tradition of specialised industrial clusters—particularly in manufacturing, fashion, and design—creates both opportunities and constraints for the adoption of sustainable practices. Regional policies, environmental regulations, and market signals interact with these localised structures, shaping firms' strategic orientations towards circularity and low-carbon production (Cainelli & Mazzanti, 2013). The systems-based approach thus underscores that innovation does not occur in isolation but depends on the alignment of technological, institutional, and socio-cultural dimensions that together enable or hinder sustainable transformation.

Circular innovation, in this conceptual framework, refers to the design and implementation of products, production processes, and business models that facilitate the transition from the traditional linear economy—characterised by the “take–make–dispose” paradigm—towards a regenerative and restorative economic system. Its core dimensions include the efficient use of material and energy resources, the extension of product lifespans through repair, reuse, and remanufacturing, the minimisation of waste generation, and the substitution of non-renewable inputs with renewable or bio-based alternatives (Ghisetti & Rennings, 2014; Mazzanti & Zoboli, 2009; Geissdoerfer et al., 2017; Kirchherr et al., 2018). In line with the definition proposed by Kemp and Pearson (2007), eco-innovation can be understood as “the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative

impacts of resource use” (p. 8). This conception highlights the dual economic and environmental rationale of eco-innovation: it simultaneously enhances competitiveness and contributes to environmental performance, thereby aligning micro-level business incentives with macro-level sustainability goals.

Within this ecosystem, small and medium-sized enterprises (SMEs) play a pivotal—albeit complex—role (Zecca and Mazzanti, 2023). SMEs often display high adaptability and responsiveness to local environmental and market conditions, which can facilitate the rapid implementation of circular practices. However, their capacity for innovation is frequently constrained by structural and resource-based limitations, including restricted financial capital, shortages of skilled personnel, and limited access to research infrastructures or innovation networks (Rizos et al., 2016; del Río et al., 2016; Pronti et al 2024). Such constraints can hinder their ability to undertake substantial investments in eco-innovation, despite their strategic positioning within local supply chains and their potential to act as key intermediaries in the diffusion of circular solutions.

Nevertheless, SMEs represent the backbone of the European and Italian economies, accounting for approximately 99% of all businesses across the European Union and generating a significant share of employment and value added (European Commission, 2023). In Italy, this structural composition is even more pronounced: SMEs dominate the private sector landscape, forming the basis of the country’s productive fabric and contributing decisively to its export performance and industrial resilience. Their deep integration into regional and sectoral networks makes them essential actors in the operationalisation of circular economy principles and in advancing the broader sustainability transition at the national level.

3. Survey design and Data

The sample of manufacturing firms analysed in this study comprises a total of 740 productive units, distributed across the entire national territory and broadly representative of the contemporary structure of the Italian manufacturing sector. The sample was stratified by firm size and macro-geographical area to ensure adequate coverage of different production contexts. The survey aims to provide a descriptive and interpretative overview of the firms’ structural and behavioural characteristics, with particular attention to aspects such as corporate group affiliation, firm size, territorial distribution, business typology, industrial sectors, and propensity towards innovation, research, and technological development during the 2023–2024 period.

The analysis therefore seeks not merely to present quantitative data, but also to offer a broader reflection on the economic significance of these figures within the Italian context—one characterised by deep structural heterogeneity and a long-standing tradition of small-scale, independent entrepreneurship.

3.1 The questionnaire

The questionnaire constitutes a comprehensive research instrument designed to collect systematic information on the structural, behavioral, and strategic characteristics of Italian firms, with particular attention to their

capacity for innovation, sustainability performance, and organizational adaptation to the twin transitions—digital and ecological—currently reshaping the economic landscape. Conceived as both a descriptive and analytical tool, it aims to capture the complexity of contemporary entrepreneurial dynamics by integrating quantitative indicators (such as investment levels, turnover distribution, and workforce composition) with qualitative elements related to managerial orientation, awareness of sustainability objectives, and innovation culture.

The questionnaire is organized into four main thematic areas, each addressing a specific dimension of firms' activity. The first section focuses on the company's general and identifying information, including legal name, location, sector, and size, as well as data on the respondent's profile—position, age, gender, educational background, and length of service within the firms. It further explores structural characteristics such as the firm's membership in a corporate group, year of establishment, production typology, and revenue class. Particular attention is devoted to innovative organizational forms, including start-ups and benefit corporations, for which additional questions investigate the use of impact indicators, familiarity with the United Nations' Sustainable Development Goals (SDGs), and alignment with specific sustainability targets.

The second section is devoted to innovation and investment activities, examining the firms' engagement in research and development over the 2023–2024 period and the proportion of turnover allocated to these purposes. It investigates the types of technological, process, and digital innovations introduced, distinguishing between those that are new to the firm, the sector, or the market. The section also collects information on the adoption of enabling technologies—such as the Internet of Things, artificial intelligence, blockchain, and digital twins—and the financing strategies employed to support innovation, including access to public funding programs or multi-banking arrangements. Furthermore, it explores the perceived effectiveness of such financial tools in sustaining both liquidity and innovation processes, providing insight into the relationship between financial structures and technological advancement.

The third section focuses on the implementation of circular economy and sustainability practices. It investigates whether firms have adopted innovations aimed at reducing resource consumption, limiting waste generation, reusing or recycling materials, and redesigning products for greater efficiency and recyclability. For each innovation, respondents indicate the degree of novelty and the financial sources mobilized—internal funds, bank loans, public subsidies, or alternative mechanisms such as green bonds or crowdfunding. Additional questions assess participation in public procurement programs, awareness of the European carbon market (ETS), and expected trends in investment for the 2025–2026 period. This part of the questionnaire also examines the integration of sustainability into corporate governance through reporting practices, strategic planning, performance monitoring, and stakeholder communication, as well as the adoption of recognized reporting standards such as GRI, ESRS, TCFD, and SDGs. Finally, it investigates perceptions of climate change, inviting respondents to express their level of agreement with statements regarding its causes, consequences, and temporal proximity.

The fourth and final section concerns organization and training, with a focus on human capital development and innovation culture. It assesses the firm's propensity to experiment with new ideas, adopt creative processes, and engage in continuous learning. Respondents are asked to provide quantitative data on the extent of employee training and to evaluate the importance of various competencies—scientific, technological, mathematical, linguistic, social, and managerial—deemed essential for innovation. The section also examines recruitment dynamics, identifying the types of professional profiles sought to sustain innovation, and the existence of partnerships or networks with other actors in the innovation ecosystem, such as universities, research centers, clusters, start-ups, and regional development agencies.

Overall, the questionnaire provides a detailed empirical framework for analyzing how Italian firms are responding to the challenges of sustainable transformation. It not only measures the diffusion of technological and organizational innovations but also interprets their broader implications in terms of environmental responsibility, social impact, and long-term competitiveness. By capturing both the measurable and intangible aspects of business behavior, it offers a multifaceted perspective on how firms evolve within a context increasingly defined by sustainability and innovation imperatives.

4. Research and Development, Innovation and Digital Transformation

With regard to research and development (R&D), data for the 2023–2024 period indicate that Italian firms still show a relatively limited tendency to invest in this field. Only 27.3% of the companies in the sample reported investments in R&D activities, while the remaining 72.7% did not allocate specific resources to this type of endeavor. This distribution reveals a scenario in which research and innovation remain the prerogative of a minority of firms, suggesting the persistence of a certain degree of caution or difficulty in committing resources to areas characterized by higher risk and less immediately measurable returns.

The propensity to engage in research varies significantly across regions: in the North-West, 35.2% of firms invest in R&D, compared to 25.6% in the North-East, 21.7% in the Centre, and only 14.5% in the South and Islands. This territorial divide mirrors the longstanding gap between the more developed and the less industrialized areas of the country, where the presence of universities, research centers, and more structured production networks contributes to sustaining innovation activities in the northern regions.

% Firms that have made R&D investments by geographical area

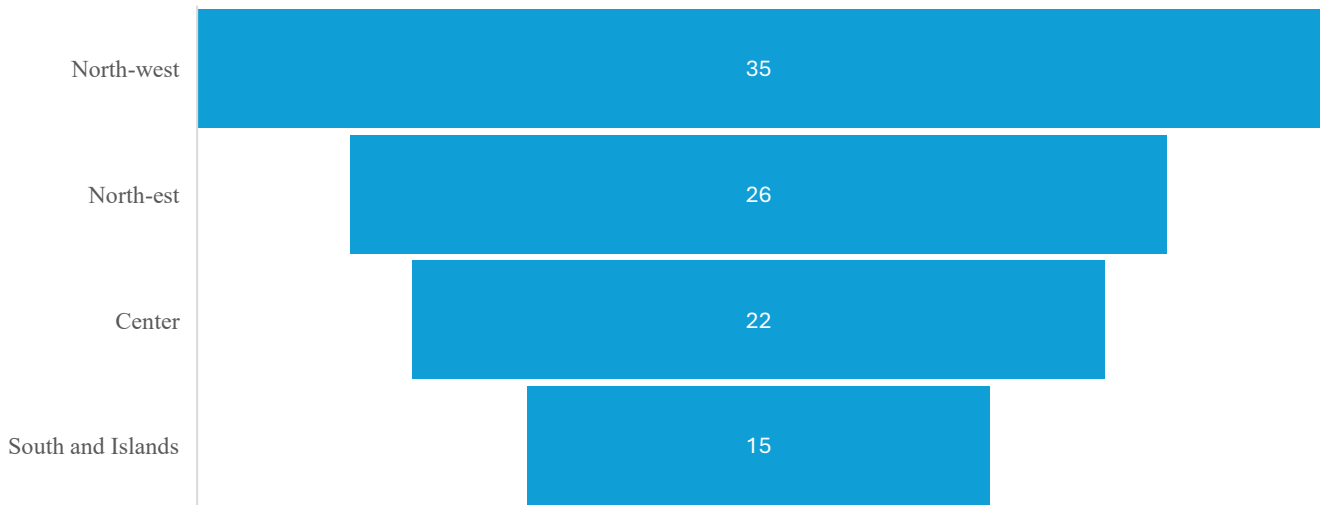


Figure 1. Percentage of firms have made R&D investments by geographical area. Own elaboration TINKER data

% Firms that have made R&D investments by number of employees

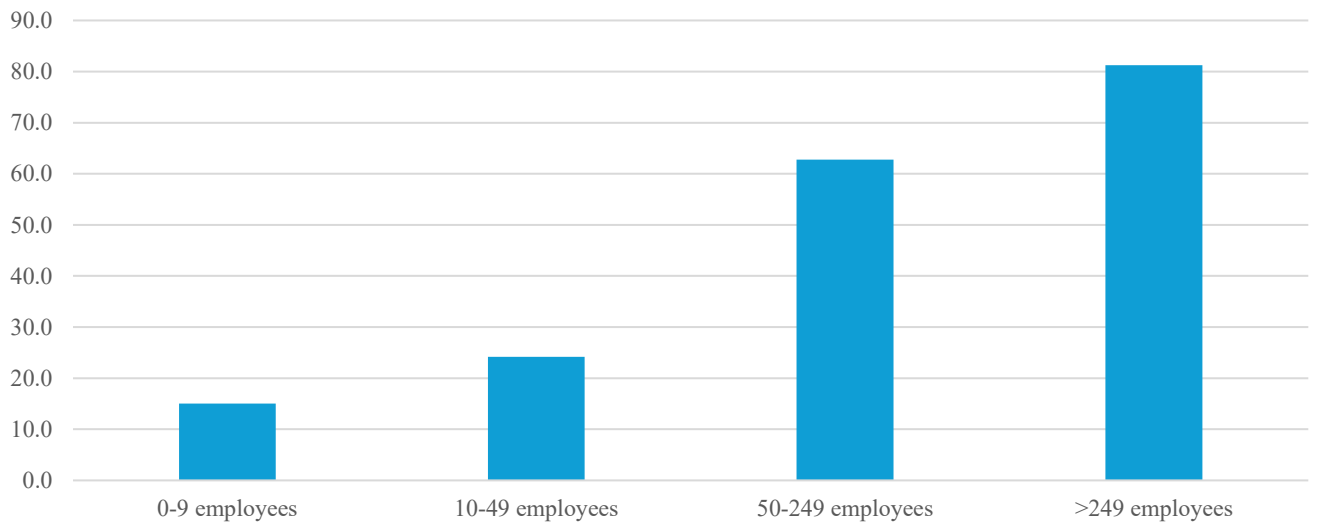


Figure 2. Percentage of firms have made R&D investments by number of employees. Own elaboration TINKER data

Firm size once again proves to be a decisive factor. Among micro-firms, only 15.1% have made investments in R&D; this share rises to 24.2% among small firms, 62.7% among medium-sized ones, and reaches 81.3% among large firms. This linear progression reflects the varying capacities of firms to absorb risk and allocate resources to research activities. Larger firms generally benefit from dedicated internal structures, qualified

personnel, and a more innovation-oriented strategy, whereas micro and small firms—often focused on day-to-day operations and market survival—tend to view research as a cost rather than a strategic investment.

The distinction between start-ups and established firms is also noteworthy. Only 14.3% of start-ups in the sample reported investments in R&D, compared with 27.4% of established firms. Although this finding may appear counterintuitive, it can be understood in light of the characteristics of the start-ups included in the sample: they represent a relatively small number of firms, often in the early stages of development, which may not yet have achieved the stability required to dedicate resources to internal research. In many cases, moreover, start-ups focus in their initial years on acquiring customers, defining their products, or consolidating their business models rather than engaging in formal research and development activities.

The analysis of product and process innovation, also referring to the 2023–2024 period, provides further insight into the capacity of Italian firms to introduce significant changes in their operations and competitive strategies. With regard to product innovation, 62.7% of firms did not introduce any relevant new products, while 24.7% developed products already existing on the market but new to the firm, and 12.6% introduced completely new innovations, even for their sector. This means that, overall, about one in three firms introduced some form of product innovation, although most of these efforts involved adaptation or incremental improvement rather than radical innovation.

Geographical disparities are again evident. In the North-West, 27.5% of firms introduced new products; in the North-East, the share was 25%; in the Centre, 22.6%; and in the South and Islands, also 22.6%. Product innovation thus appears more widespread in the northern regions, where firms are more deeply integrated into technological districts and global value chains. Nonetheless, the phenomenon is not absent in other areas of the country, indicating a broader—albeit still uneven—process of modernization.

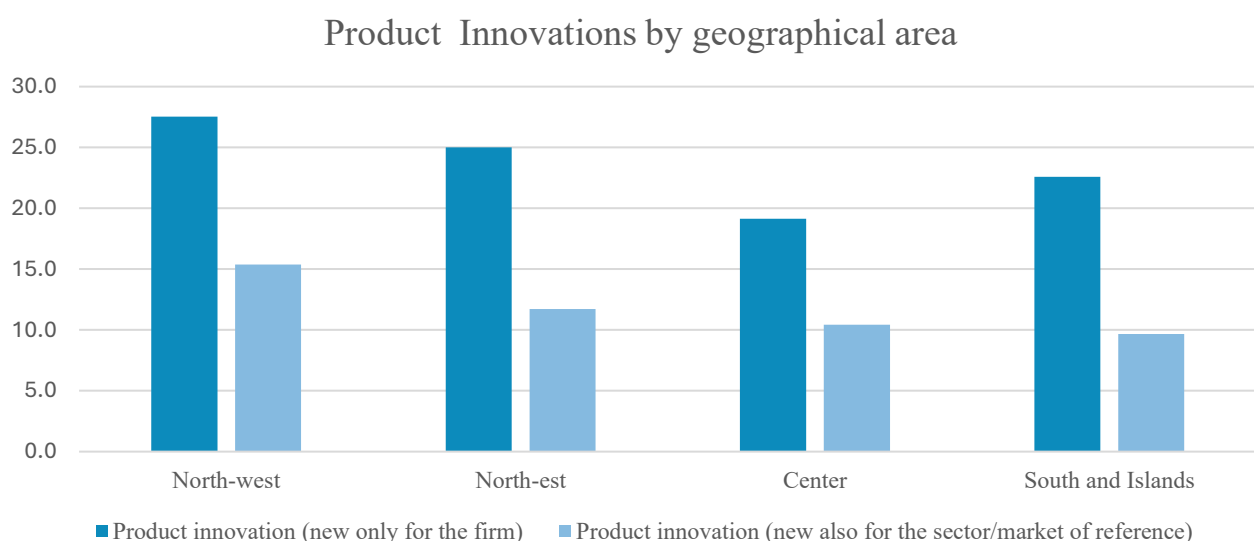


Figure 3. Product Innovations by geographical area. Own elaboration on TINKER data

With regard to process innovations, the data reveal a similar situation, albeit with some notable differences. During the 2023–2024 period, 62.2% of firms did not introduce any process innovations, 32.0% implemented processes that were new to the firm but already known within the sector, and 5.8% introduced process innovations that were entirely new even for the industry as a whole. Although this result indicates that a majority of firms remain stable in their production methods, it nonetheless highlights a non-negligible capacity for experimentation, particularly among medium-sized and large firms. From a geographical perspective, the propensity to innovate in production processes is highest in the North-West, where 36.8% of firms introduced such innovations, followed by the North-East with 32%, the Centre with 26.1%, and the South and Islands with 27.4%.

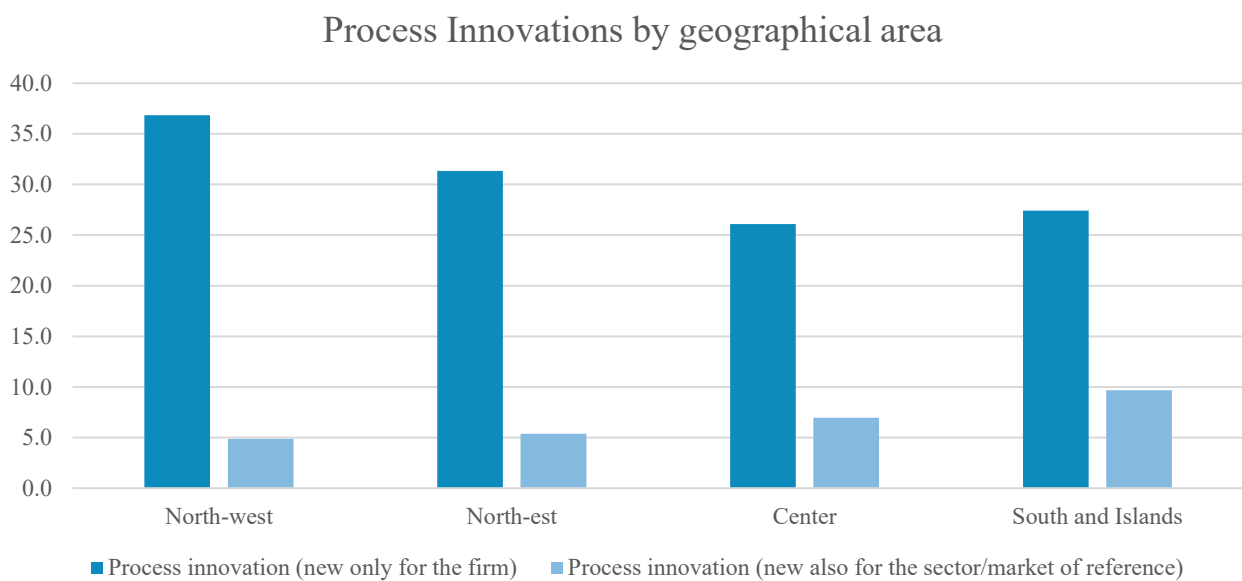


Figure 4. Product Innovations by geographical area. Own elaboration on TINKER data.

The relationship between process innovation and firm size is even more pronounced than that observed for product innovation. Among micro-firms, only 19.7% reported having introduced process innovations; this share rises to 35.0% among small firms, 52.9% among medium-sized firms, and 50.0% among large ones. This indicates that the ability to introduce process innovations does not increase in a strictly proportional manner with firm size but tends to stabilize at higher levels. This suggests that some large firms, despite having substantial resources, do not continuously innovate their production systems—possibly due to organizational rigidity or already consolidated investments

The situation of start-ups, however, appears to be quite different: 71.4% of them have introduced process innovations. This figure is particularly significant and suggests that new firms, though relatively few in number, represent a key driver of innovation—especially in terms of reorganizing production processes and experimenting with new operational models. It is plausible that many of these process innovations involve the

introduction of digital technologies, leaner production models, or advanced management systems—elements that are often integrated into start-ups from the earliest stages of their development.

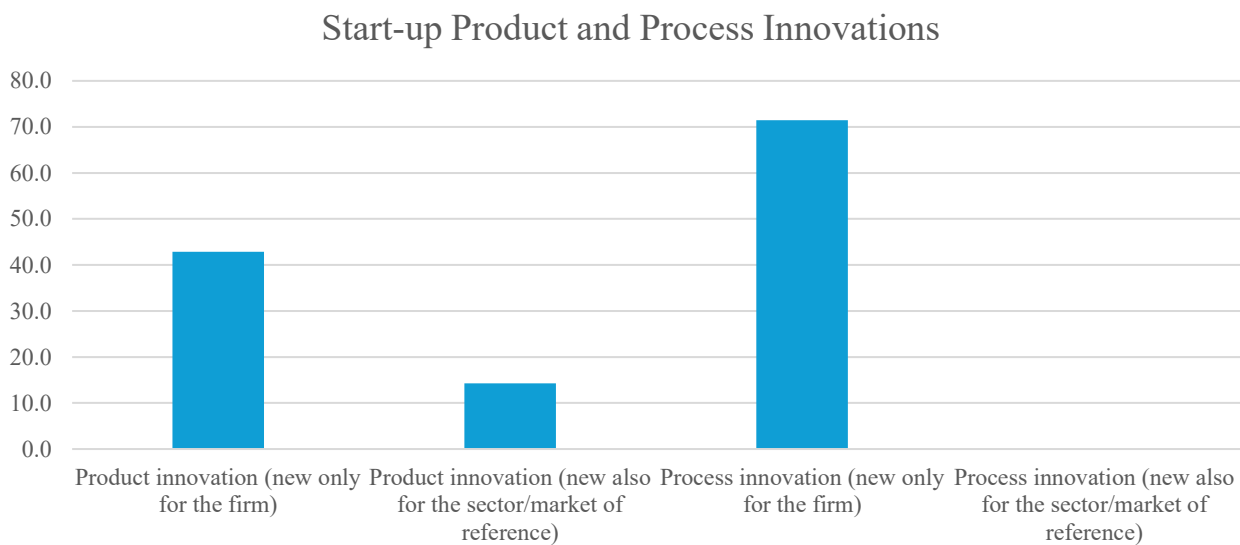


Figure 5. Start-up Product and Process Innovations. Own elaboration on TINKER data.

The analysis of data on digital innovations provides further insight into this picture. During the 2023–2024 period, 20.0% of firms adopted new Internet-based technologies, 5.7% introduced artificial intelligence (AI) applications, and 22.4% implemented other forms of digital innovation, such as integrated management systems, process automation, or data analytics solutions. Although these percentages may appear modest, they point to an ongoing process of digitalization, driven mainly by larger firms and by those located in northern regions. In particular, the North-West records the highest values both for the adoption of Internet technologies (22.7%) and for the use of AI applications (8.5%). These are followed by the North-East and Central Italy, where values range between 17% and 21%, while in the South and Islands the spread of digital innovations remains more limited.

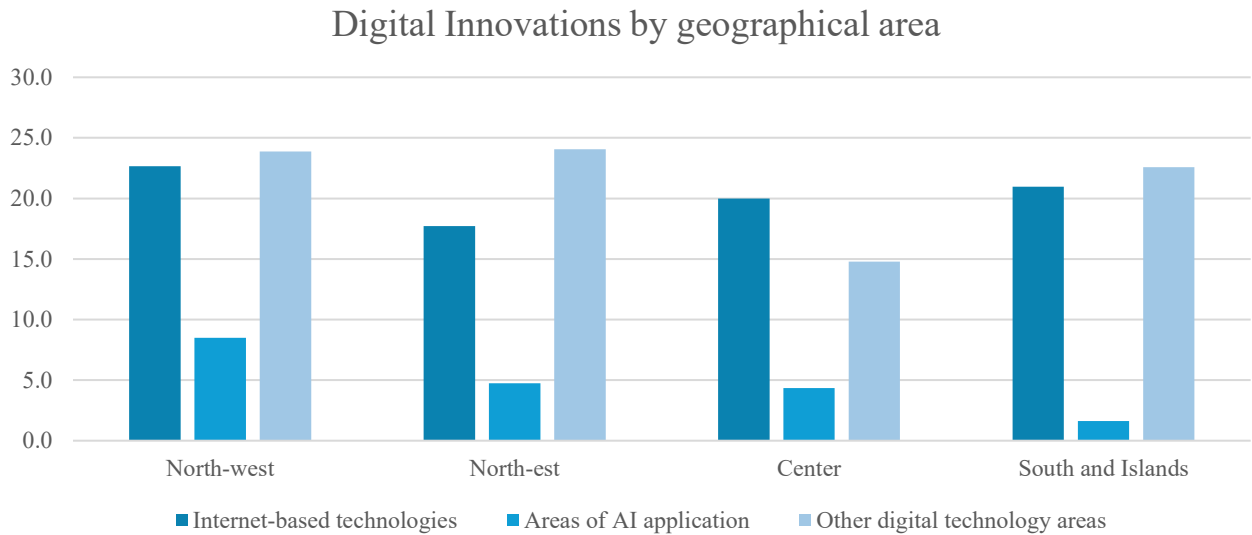


Figure 6. Percentage of digital Innovations by geographical area. Own elaboration on TINKER data.

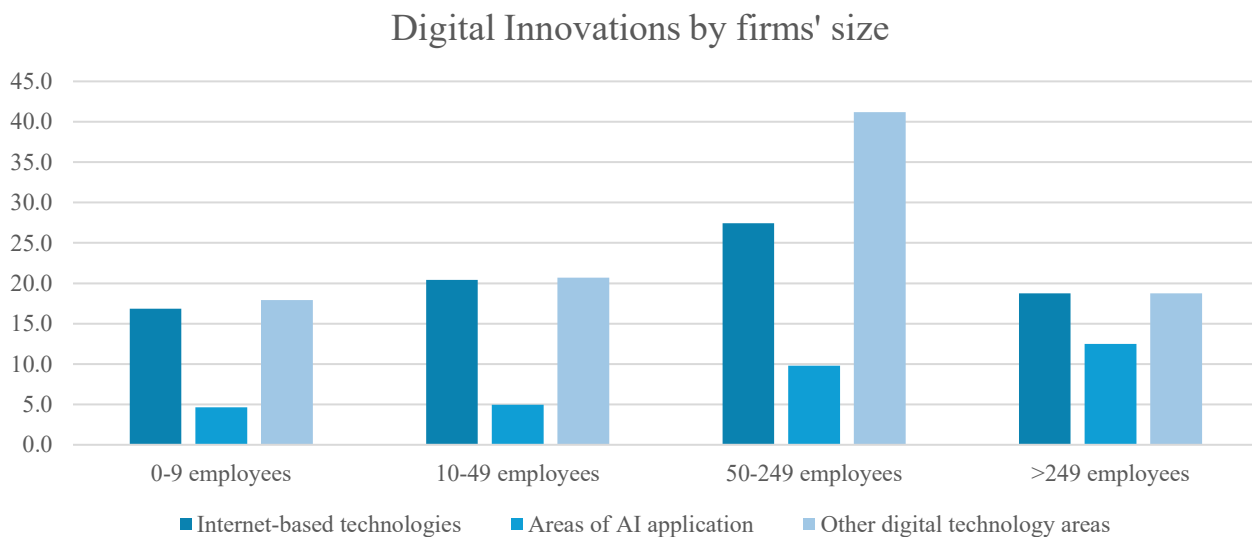


Figure 7. Percentage of digital Innovations by firms' size. Own elaboration on TINKER data.

The combined analysis of information on innovation, digitalization, and group affiliation makes it possible to outline a coherent yet complex picture of the Italian productive structure. On the one hand, there is a broad base of small, independent firms with a low propensity to invest in research and development; on the other, there exists a narrower segment of medium and large firms, often belonging to corporate groups, that exhibit strong innovation activity and a more advanced level of digitalization. These two models coexist within the national production system and define its dual nature: a multitude of small, autonomous firms—highly rooted in local contexts, flexible yet resource-constrained—and a smaller number of structured firms, oriented toward growth and internationalization. The divide between the two poles is not only dimensional but also cultural and strategic. Small-scale firms tend to conceive innovation as an incremental process aimed at maintaining

local competitiveness, whereas large firms and start-ups innovate in a systemic way, integrating research and digitalization into their overall business strategy.

The territorial analysis of the data links these differences to the economic and infrastructural context of the various regions of the country. Firms in the North—particularly in the North-East and North-West—benefit from consolidated industrial districts, the presence of universities and research centers, as well as widespread networks of suppliers and technical expertise. These factors create a favorable environment for innovation and collaboration among firms. In Central Italy, the productive fabric is more fragmented but includes several sectoral excellences, especially in manufacturing and advanced services. The South and Islands, however, continue to face structural disadvantages due to lower infrastructure investment, weaker industrial networks, and the limited presence of technological hubs. Despite this, some firms in the Mezzogiorno show interesting growth dynamics, particularly in emerging sectors related to digital technologies, tourism, and high-quality agri-food production.

A cross-cutting element emerging from the survey concerns the relationship between firm size and innovative capacity. The data clearly show that organizational scale significantly affects the propensity to invest in research and to introduce product and process innovations. Larger firms possess not only greater financial resources but also more diversified internal expertise and organizational structures capable of managing research complexity. They are also more likely to participate in collaborative networks and joint innovation projects—factors that strengthen their ability to develop new solutions. Conversely, micro and small firms, while often more agile and responsive, face difficulties in sustaining long-term investments and tend to focus on incremental improvements. The lack of specialized personnel, limited access to credit, and scarcity of public support instruments further hinder the diffusion of innovation within this segment.

Another key aspect highlighted by the data concerns the relationship between innovation and territory. Northern regions exhibit higher innovation intensity not only for structural reasons but also because of the presence of a more favorable ecosystem. In these areas, universities, technology parks, business incubators, and research centers act as catalysts for innovation. Regional policies—particularly in Lombardy, Emilia-Romagna, Veneto, and Piedmont—have encouraged collaboration between firms and academia in recent years, creating an environment where knowledge circulates more freely. Conversely, in Central and Southern Italy, innovation tends to be more fragmented and often linked to isolated initiatives or specific districts. This confirms the importance of the territorial context as an enabling factor for innovation, one that extends beyond a firm's internal characteristics and reflects the quality of the economic and institutional environment in which it operates.

A further element of interest is the role of digitalization as a cross-cutting driver of competitiveness. During the 2023–2024 period, the spread of digital technologies had a significant impact even among smaller firms, though it remained more pronounced among medium and large firms. The data show that only 20.0% of firms adopted new Internet-based technologies, but this percentage increases progressively with firm size, reaching nearly 81% among the largest firms. Artificial intelligence applications—still in an experimental phase within

the Italian productive system—were implemented by 5.7% of firms, while other digital technologies, including automation systems, advanced management software, data analysis applications, and e-commerce tools, were adopted by 22.4% of firms.

The analysis of these data reveals that digitalization is not a uniform process but rather a stratified phenomenon that advances at different speeds depending on the sector, firm size, and geographical area. Firms in the North-West—more exposed to international competition and integrated into global supply chains—show the greatest propensity to adopt digital tools, with 22.7% using Internet-based technologies and 8.5% implementing artificial intelligence applications. The North-East and Central regions record slightly lower but still significant values, ranging between 17% and 21%. Firms in the South and Islands appear more delayed, both due to limited digital infrastructure and to a weaker technological culture. Nonetheless, positive signals are emerging even in these areas, particularly among younger firms and those operating in advanced services or tourism, which are gradually adopting digital solutions to enhance their competitiveness.

The relationship between digitalization and innovation emerges clearly when comparing firms that have introduced product or process innovations with those that have invested in digital technologies. In almost all cases, the firms that innovate are also those that adopt digital tools. Digitalization represents not only a field of innovation but also an enabling condition for innovation itself: it allows for improved process management, real-time data analysis, product customization, and cost reduction. From this perspective, digital transformation can be viewed as an indicator of a firm's innovative maturity. The fact that start-ups—although numerically marginal—display higher-than-average rates of digital technology adoption (28.6% using Internet-based technologies and 42.9% implementing other forms of digital innovation) suggests that they are playing a pioneering role in the transformation of the Italian production system.

The relationship between size, innovation, and performance also has a qualitative dimension: larger firms not only innovate more but do so differently. Their research and development activities are typically systematic, integrated into strategic planning, and aimed at achieving long-term competitive positioning. Smaller firms, on the other hand, tend to innovate in a more reactive and fragmented manner, often in response to short-term needs or market pressures. This difference in approach also translates into differing economic impacts: the innovations of larger firms tend to generate broader effects along the supply chain and within the territory, while those of smaller firms remain more localized, albeit quicker and more flexible in implementation.

Another interpretative dimension concerns the nature of the productive sectors involved. Although this analysis do not explicitly distinguish between economic sectors, it can be inferred that firms investing most in research and development largely belong to high-tech manufacturing sectors—such as advanced mechanics, electronics, and chemistry—or to knowledge-intensive services, such as information technology and professional consulting. Less innovation-oriented firms are concentrated in traditional sectors, including commerce, crafts, and small-scale manufacturing, where competition often revolves around cost rather than differentiation. The coexistence of these two productive models—one innovative and globalized, the other local and traditional—is a defining feature of the Italian economic system and represents both a limitation and a resource. On the one

hand, fragmentation reduces the country's overall capacity to implement integrated industrial policies and to scale up innovations; on the other, the diversity of the entrepreneurial fabric ensures resilience and adaptability in times of crisis.

From a temporal perspective, the data referring to the 2023–2024 biennium fit into a particularly complex economic context, marked by post-pandemic effects, geopolitical tensions, and the challenges of digital and ecological transition. In this scenario, many Italian firms have had to revise their operational strategies, attempting to balance cost containment with the need to innovate in order to remain competitive. The relatively low level of investment in research and development—only 27.3% of firms being involved—can also be interpreted in light of this uncertainty, which has led many firms to postpone strategic decisions until conditions become more stable. However, the growing diffusion of digital innovations and the significant share of smaller firms that have embarked on innovation processes indicate an underlying trend toward transformation.

The territorial differences highlighted by the data remain among the most relevant and persistent features. The North continues to host the majority of the most innovative and digitalized firms, thanks to a more favorable infrastructural and institutional context. In the Center and South, innovation phenomena appear more sporadic but not insignificant, often linked to individual initiatives or specific projects supported by public funds. The challenge for the coming years will be to reduce this gap, creating more homogeneous conditions for growth and innovation across the national territory. This will require strengthening policies supporting small and medium-sized firms, enhancing technical and managerial training, and expanding collaborative networks among firms, universities, and research centers.

4.1 Circular Innovation Strategy

The graph below illustrates the diffusion of various types of circular innovation among firms. The percentages on the vertical axis indicate the share of firms that have introduced each type of innovation. Among the most widespread practices are the reuse of electricity (approximately 38%) and the use of renewable energy (around 34%), followed by the reduction of materials and the reduction of waste (both about 29–30%). Less frequent measures include the reuse of waste in the production process (20%) and the transfer of waste to other firms (25%). Eco-design strategies, such as designing products to minimize raw material use (16%) or to maximize recyclability (13%), are even less common. The least adopted measure is the reduction of emissions, reported by just over 10% of firms. Overall, the chart suggests that the most common circular innovations are those that allow for direct savings in resources and energy costs, whereas more complex and systemic strategies—such as product redesign or industrial symbiosis—remain less widespread, likely due to the higher levels of investment, coordination, and technological capabilities they require.

National policies, such as the Italian Circular Economy Action Plan and the measures included in the National Recovery and Resilience Plan (PNRR), aim to address these gaps by promoting investment in green technologies, energy efficiency, and digitalization. Yet, for the circular transition to become systemic, scholars

underline the need to integrate innovation, territorial cooperation, and institutional support, promoting a vision in which circularity is not only an environmental objective but also a key driver of competitiveness and resilience for the productive system.

The map titled map illustrates the geographical distribution of circular innovation initiatives across Italian regions. The color gradient indicates the intensity or number of circular innovations, with darker shades representing higher concentrations.

The map clearly reveals a pronounced regional divide: northern regions, particularly Lombardy, Veneto, and Emilia-Romagna, show the highest levels of circular innovation activity. These areas are characterized by dense industrial districts, higher levels of technological development, and a stronger presence of medium and large firms, which are more likely to invest in research and development related to sustainability and circularity.

Central regions, such as Tuscany and Marche, display intermediate levels of engagement, while southern regions and the islands show lower levels of circular innovation. This pattern reflects broader structural and economic disparities across the country. The limited diffusion of circular practices in southern regions may be associated with the smaller average size of firms, lower investment capacity, and weaker institutional and technological infrastructures.

It should be noted that no data are available for the Calabria region. This absence is due to the sampling design of the survey, which was stratified by macro-geographical area rather than by individual regions.

Overall, the map highlights the persistence of a north–south divide in Italy’s transition toward circular economy practices. This spatial heterogeneity underscores the need for targeted regional policies aimed at fostering innovation ecosystems, enhancing inter-firm cooperation, and strengthening institutional support, so that less developed regions can participate more effectively in the circular transformation.

Circular innovations

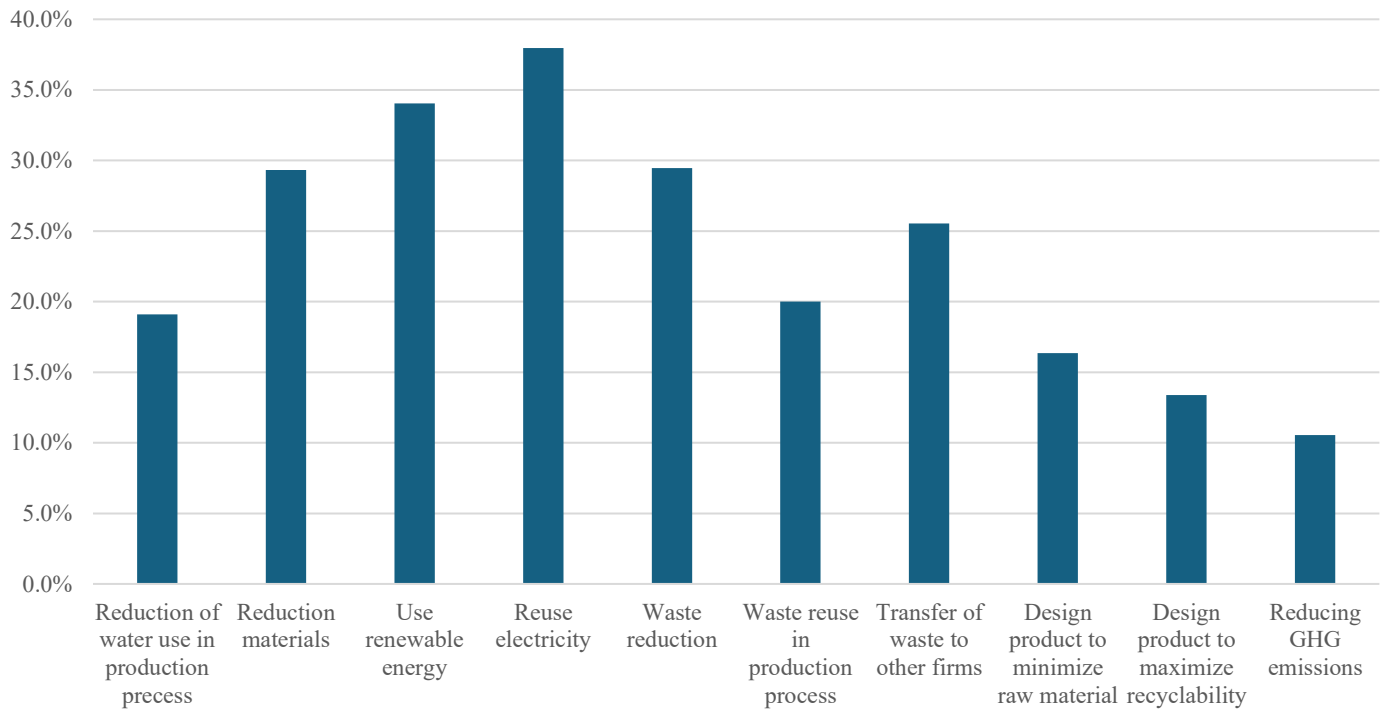
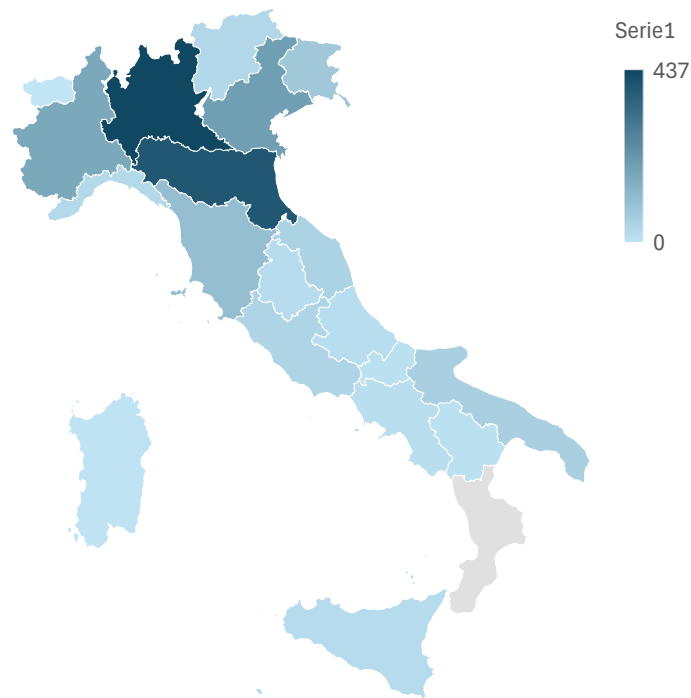


Figure 8. Percentage of circular innovation introduced by firms. Own elaboration on TINKER data



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Figure 9. Percentage of circular innovations introduced by Italian regions. Own elaboration on TINKER data.

5. Conclusions

The evidence presented in this work highlights both the achievements and persistent asymmetries shaping the sustainability and innovation landscape of Italian manufacturing firms. The empirical findings confirm that the transition towards a sustainable and digitally integrated production model is underway, yet still uneven across firm sizes, sectors, and regions. The coexistence of highly innovative and digitally advanced firms alongside a vast number of smaller firms with limited resources underscores the structural dualism of the Italian economy. This divide not only reflects differences in capital endowment and organizational capabilities but also reveals distinct cultural and strategic orientations toward innovation, where smaller firms tend to privilege incremental adjustments and cost-saving measures, while larger firms and start-ups pursue systemic and transformative innovation trajectories.

The survey results indicate that research and development activities remain concentrated within a relatively restricted segment of firms—mainly medium and large firms located in the northern regions. These firms benefit from more favorable ecosystems, including dense industrial districts, technological infrastructures, and collaborative networks with universities and research centers. Conversely, firms in the Centre and South, despite some promising experiences, continue to face significant structural constraints related to limited financial capacity, inadequate infrastructure, and weaker innovation ecosystems. The persistence of such territorial divides represents a major policy challenge, as it risks perpetuating regional inequalities and constraining the national potential for sustainable growth.

Digitalization emerges as both a driver and an enabler of innovation. The adoption of digital tools such as artificial intelligence, Internet-based technologies, and automation systems is strongly associated with higher levels of innovation performance, confirming the complementarity between technological upgrading and sustainability-oriented transformation. However, the diffusion of digital technologies remains fragmented and largely dependent on firm size, revealing a pattern of innovation stratification rather than diffusion. Start-ups play a distinctive role in this process, showing a comparatively higher propensity to adopt advanced digital solutions and to integrate them into new production and business models. Their contribution, though limited in scale, signals the potential for renewal within the Italian production system, particularly in high-value and knowledge-intensive sectors.

In relation to circular innovation, the data suggest that most Italian firms are at an early stage of adoption, focusing primarily on efficiency-oriented measures such as energy reuse and waste reduction. More systemic and design-based strategies—such as product eco-design or industrial symbiosis—remain relatively marginal. This reflects the broader pattern observed across European economies, where circular practices tend to emerge first through operational optimizations before evolving into comprehensive business model innovations. The regional distribution of circular innovation practices confirms the broader north–south divide, with northern regions displaying higher engagement thanks to their stronger industrial

and institutional capacities. The absence of data for certain regions, due to the macro-area stratification of the sample, does not diminish the general conclusion that spatial disparities continue to shape Italy's sustainability transition.

Overall, the findings point to a gradual yet tangible reorientation of Italian SMEs towards sustainability and digitalization. Despite resource limitations, many firms are integrating environmental and technological objectives into their strategies, motivated by cost-efficiency considerations, regulatory incentives, and growing market awareness. Nevertheless, the persistence of financial, organizational, and knowledge-related barriers highlights the importance of supportive policy frameworks. Initiatives such as the National Recovery and Resilience Plan (PNRR) and the Transizione 4.0 program constitute important steps in this direction, yet their long-term effectiveness will depend on the capacity to coordinate interventions across scales—linking national, regional, and local actors—and to address not only technological gaps but also human capital development and institutional alignment.

From a theoretical perspective, the results reinforce the notion that sustainability transitions are systemic processes requiring multi-level coordination among technological, institutional, and social dimensions. The transformation of SMEs—given their structural centrality within the Italian economy—cannot rely solely on technological diffusion; it demands an integrated approach encompassing skills enhancement, collaborative networks, and the creation of inclusive innovation ecosystems. Policy instruments should therefore move beyond isolated incentives and adopt a systemic vision that connects circular innovation, digital transformation, and regional development. Only through such coordination can the Italian productive system transform its heterogeneity into a strategic advantage, combining local embeddedness with technological sophistication.

In conclusion, while the transition toward sustainability in Italy remains incomplete, the trends identified in this report suggest a path of progressive adaptation rather than resistance. The dual nature of the Italian productive fabric—composed of both resilient traditional firms and dynamic innovative firms—represents not a weakness but a potential resource for a plural and regionally diversified sustainability transition. To fully harness this potential, future policies and research efforts should focus on bridging structural divides, fostering inter-firm cooperation, and embedding sustainability within the cultural and strategic core of Italian entrepreneurship. In doing so, Italy can not only enhance its competitiveness but also contribute meaningfully to Europe's broader goal of building a climate-neutral, inclusive, and innovation-driven economy

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