Assessing the Competitiveness of Italian Firms Patenting in Circular economy

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Abstract

This paper analyses the relationship between circular economy (CE) innovation and firm performance using a unique firm-level dataset integrating financial indicators, strategic variables and CE-related patent technologies identified via machine learning techniques. The focus is on Italian manufacturing firms during the 2019-24 period. The study combines descriptive analysis and econometric methods (probit analysis, propensity score matching techniques, Heckman selection model) to investigate both the determinants of firms' involvement in CE activities and the impact of such innovation on financial KPIs, with a focus on productivity. Results show that firms patenting in CE display a more advanced strategic profile, with stronger internationalization, greater adoption of renewable energy and broader sustainability-oriented practices. Moreover, circular firms proved to be resilient to macroeconomic shocks in 2019-24, by maintaining stable margins and showing higher levels of capitalization and labour productivity with respect to non-circular firms. Econometric estimates suggest a positive association between CE innovation and productivity growth, but the effect becomes statistically insignificant when controlling for firm heterogeneity through matching techniques. Overall, the findings highlight that circularity is embedded in broader strategic and organizational skills at the firm level, which are important for calibrating future interventions that can trigger a virtuous cycle of growth for the national economy.

Keywords and JEL Codes: Circular economy (F64, Q50, Q53), Technological Innovation (Q55); Environment and growth (O44); Firm Behavior: Empirical Analysis (D22); Total Factor Productivity (D24).

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Introduction and literature review

The relationship between firms' performance and innovation within the specific context of the Circular Economy (CE) is still in its early stages of analysis in the economic literature.

A significant area of debate focuses on identifying suitable indicators for measuring CE value, including the potential use of patents for this purpose. While innovation can occur without patenting in many fields, the Circular economy is closely connected to technological innovations, which are more frequently patented than other types of innovations. A Circular business model can in fact be achieved by reducing dependence on raw materials and energy through innovations, by focusing on waste minimisation, and by creating Circular (closed) loops where raw materials and resources are re-used repeatedly across production phases. We can therefore assume patents registered to protect technology innovations related to the CE model adopted by a firm can be used as a proxy for Circular innovation. This approach is in line with previous studies on this topic (Portillo-Tarragona et al., 2022; Fusillo et al., 2021; Modic et al., 2021; Hysa et al., 2020; Prieto-Sandova et al., 2018).

This research seeks to contribute to the economic debate by analysing whether investments in Circular patents can improve firms' performance, as measured by sales growth and profitability ratios. Moreover, we will investigate the relationship between innovation and productivity (both labour productivity and total factor productivity (TFP)), which is still a relatively unexplored area of study when it comes to CE.

It is important to understand if and to what extent the adoption of strategies aiming at environmental sustainability may limit firms' efficiency and profitability or, conversely, provide a competitive advantage. The debate on this is still open. A first strand of literature (mainly attributable to the contributions of Jaffe et al, 1995 and Jenkins, 1998) focuses on the increase in costs (both fixed and variable ones) that is associated with regulatory environmental obligations. Environmental strategies subtract resources from firms' core business, leading to a decrease in profitability, productivity and a consequent loss of competitiveness. Over time, however, a very different perspective has emerged in the literature. According to "Porter's hypothesis", there exists a strong link between environmental regulation and competitiveness (Porter and Van der Linde, 1995). Environmental regulation can in fact push companies to adopt strategies, particularly in terms of innovation, which can in turn translate into an improvement in business performance. The main channel is cost reduction: a decrease in the cost of raw materials (including energy) can generate a positive effect on the cost of capital and labor. Moreover, the adoption of sustainable strategies could lead to an increase in sales and profitability, by pushing for product differentiation, creation of market niches, development of specific technologies and, ultimately, increases in productivity.

The presence of a positive correlation between green innovation and firm performance can be found in several recent micro-level studies (Mingxia Liu et al., 2024; Sangalli and Trenti, 2014; Albertini, 2013; Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Al-Tuwaijri, 2004[1] , among others). Moreover, recent contributions on circular economy business models (Zara, 2021) highlight how circular strategies go beyond traditional green innovation, as they involve a structural reconfiguration of firms' investment decisions, cost allocation patterns and asset composition, with potential implications for both firm profitability and risk-return dynamics.

Our analysis will contribute to this second strand of the literature by focusing specifically on the less explored intersection between Circular Economy innovation and manufacturing firms' performance. We leverage from the map of circular patents developed by Manera and Quatraro (2025) within the context of the GRINS (Growing Resilient, Inclusive and Sustainable) multidisciplinary project (an alternative mapping of CE patents is proposed in Lanza and Zucchiatti (2025)). Moreover, the analysis s complementary to the emerging evidence from GRINS research activities, which point in the direction to examine the relationship between circular economy practices and firms' financial and innovation performance (Ginesti and Sabato, 2025; Prisco, 2025; Spagnuolo, 2025), and to investigate skill requirements and firm-level dynamics associated with the circular transition in the Italian manufacturing industry (Antonietti and Luzzago)[2].

Dataset and Metodology

The empirical analysis exploits a rich firm-level dataset of Italian companies owned by the Intesa Sanpaolo Research Department. The dataset comprises financial KPIs (Key Performance Indicators) and qualitative variables representing firm strategies, such as trademarks (source WIPO, World Intellectual Property Organization), ISO green and quality certifications obtained by firms (source Accredia, Ente Italiano di Accreditamento), foreign direct investments (source Reprint, Milan Polytechnic). Moreover, the dataset has been enriched with information on applications for Circular patents submitted to the European Patent Office (EPO). Circular patents

[1] Molina-Azorin J.F, 2009 and Iraldo at al., 2022, offer a good review of the literature on green management and financial performance, and on the links between environmental regulation and competitiveness.

[2] For a more detailed review of the recent research papers published within the GRINS context, see "Manual of CE Innovation", Spoke 5, Work Package 1, Deliverable D5.1.2 (Owner Università degli Studi di Torino, Università degli Studi di Bergamo; Contributors: Intesa Sanpaolo, Politecnico di Milano, Prometeia, Università degli Studi di Bergamo, Università degli Studi di Torino), 2025. https://grins.it/output/manual-ce-innovation

have been identified through machine learning algorithms developed by the University of Turin (see Manera and Quatraro, 2025). Our unique database allows to identify where companies active in the CE context are located and whether they are more competitive with respect to firms that are active in the same industries but are not "Circular".

The First section of the paper provides descriptive evidence on the distribution of Italian firms patenting in the Circular Economy field, both from a sectoral and a regional perspective. The Second section will focus instead on the competitiveness of CE companies. We can measure competitiveness through various KPIs, based on balance sheet data, such as turnover growth and profitability ratios (gross profit margin[3], ROI - Return on Investment[4], ROE – Return on Equity[5]). Moreover, the database allows us to estimate employment growth, labour productivity and total factor productivity at the firm level. The Third section of the paper focuses on the econometric approach. We first apply a *probit model* to investigate the determinants of the circular economy cluster (i.e. firm strategies, size-related factors, sector-related factors) and then estimate a two-step *Heckman selection model* in order to analyse the impact of CE investments on firm productivity (both labour productivity and total factor productivity).

3 Gross profit margin is a profitability ratio that measures what percentage of revenue is left after subtracting the cost of goods sold. The cost of goods sold refers to the direct cost of production and does not include operating expenses, interest, or taxes.

4 Return on Investment (ROI) is the ratio between net income (over a period) and investment (costs resulting from an investment of some resources at a point in time).

5 Return on equity, more commonly displayed as ROE, is a profitability ratio measured by dividing net profit over shareholders' equity. It indicates how well the business can utilize equity investments to earn profit for investors.

1. Preliminary map of firms patenting in Circular Economy

Within the dataset of Italian companies belonging to the Intesa Sanpaolo Research Department, we have identified 2.238 firms that have applied for Circular Economy patents at the European Patent Office (EPO). These companies, most of which are manufacturing firms (70% of all firms with at least a CE patent), account for 11.2% of the total innovative firms in our database (12.8% of the manufacturing firms with an active patenting activity)[6].

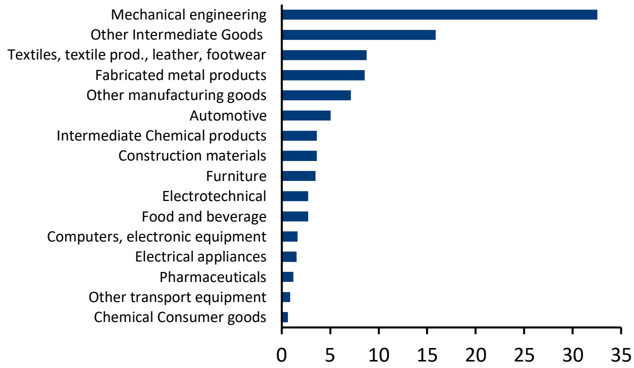
Within manufacturing, most of the firms patenting in CE (32.5%) are specialised in the Mechanical engineering sector. These firms account for 13.4% of the mechanical engineering companies which are directly involved in a patenting activity. For what concerns the mechanical engineering subsectors, almost one third of the companies in the sample are specialised in other general-purpose machinery. These are followed, in order of importance, by machinery for the textile industry, machinery for the plastics industry, other special-purpose machinery, agricultural machinery and machinery for the food industry, with shares (over the total number of Circular companies which are specialized in mechanical engineering) ranging from 9.6% to 7.1%.

Firms specialised in Other Intermediate Goods (including wood, paper, rubber and plastic products) rank second, representing 15.9% of CE patenting firms and 20.1% of all innovative companies active in the same industry. The percentage is even higher in the Textiles, textile products, leather and footwear sector: 23.5% of the innovative firms active in this sector have CE patents (they represent 8.8% of all the CE patenting firms in our dataset). Among all other industries the ranking is as follows (from highest to lowest share of Circular patents): Fabricated metal products, Other manufacturing goods[7], Automotive (motor vehicles, trailers and semi-trailers, motorcycles), Construction materials, Intermediate Chemical products; Furniture; Food and beverage; Electrotechnical; Computers and electronic equipment; Electrical appliances; Pharmaceuticals; Other transport equipment; Chemical Consumer goods (cosmetics, cleaning products). Even if we look at the sectoral breakdown in terms of 2024 revenues, the sample is highly concentrated, with Mechanical engineering in the first place, followed by the Automotive sector.

6 Excluding sectors where CE patents are not present (NACE Rev.2 codes: 5, 49, 51, 55-56, 58-60, 66, 78-81, 85-88, 90, 92-93).

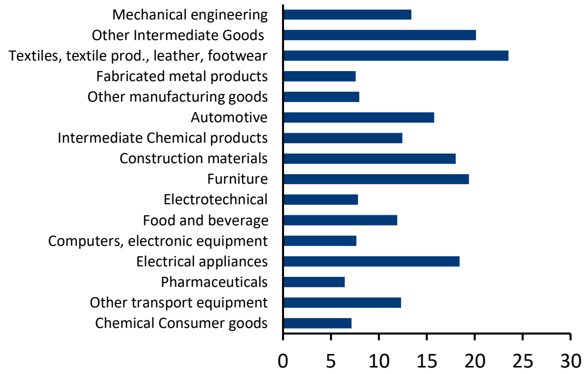
7 Other manufacturing goods includes Biomedical, Sports equipment and Precision engineering

Fig. 1 – Manufacturing firms patenting in the CE field: sectoral breakdown



Source: Intesa Sanpaolo Integrated Database (ISID)

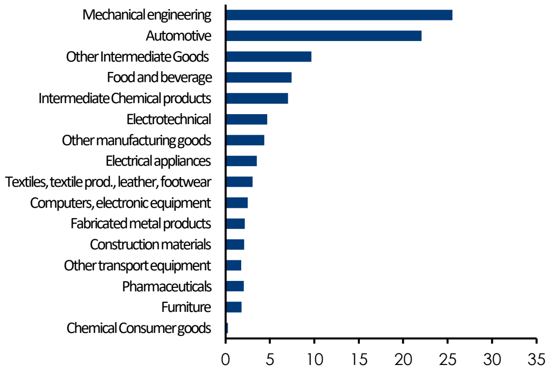
Fig. 2 – CE firms as a % share of innovative firms with a similar specialization (the sectoral ranking is identical to Fig. 1)



Source: Intesa Sanpaolo Integrated Database (ISID)

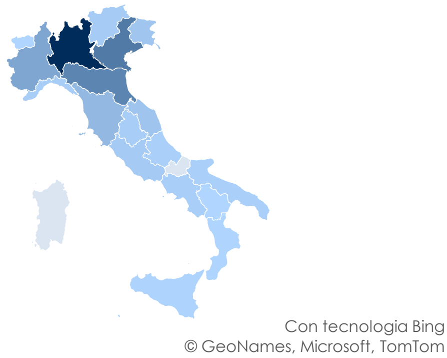
From a territorial perspective, CE firms are mostly located in three regions: Lombardy (32.6%), Veneto (17.7%) and Emilia-Romagna (15.6%). The three regions together account for 65.9% of the overall companies patenting in the CE field that are included in our database. Except for Piedmont (9.2%) and Tuscany (5.6%), all remaining regions show a percentage of CE patenting firms that is lower or equal to 3.5%. Mechanical engineering also plays a dominant role at the territorial level: the percentage of CE patenting firms specialized in machinery is 24.7% in Lombardy region, 11.6% in Veneto region and 35.8% in Emilia-Romagna region.

Fig. 3 – Revenues of the CE sample (2024): % breakdown by sectors



Source: Intesa Sanpaolo Integrated Database (ISID)

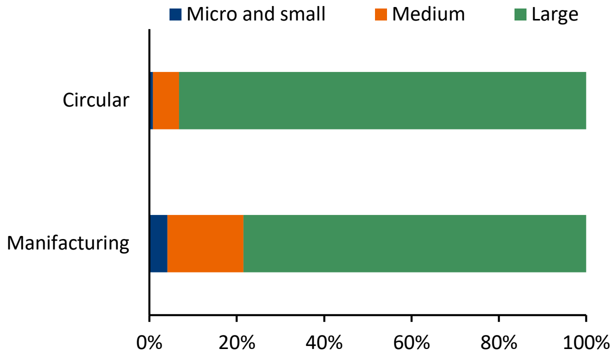
Fig. 4 - Manufacturing firms patenting in the CE field (as a % of total firms), by geographical location



Source: Intesa Sanpaolo Integrated Database (ISID)

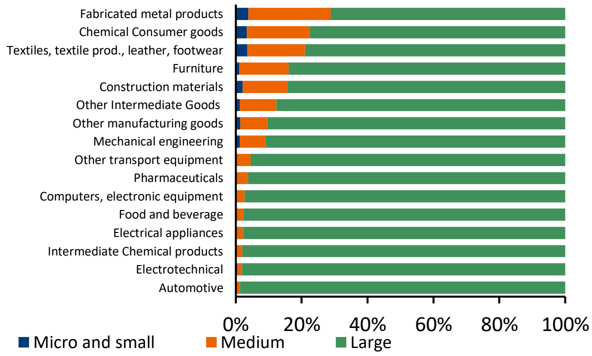
The merging process between CE patents and balance sheets has led to the identification of 913 Circular manufacturing companies active in the 2019-24 period, to be compared with 6.238 manufacturing firms which are non-Circular patent holders active in the same sectors of specialization. In terms of size[8], large enterprises dominate the Circular sector, accounting for 93% of the sample – a % higher than the manufacturing sector average of 79%. This suggests that innovation in the Circular sector requires well-structured organizational frameworks and adequate financial resources.

Fig. 5 – Revenues: breakdown by size categories (average % share over 2022–24)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 6 – CE Revenues: breakdown by sector and size categories (average % share over 2022–24)



Source: Intesa Sanpaolo Integrated Database (ISID)

In sectors such as Automotive, Intermediate Chemical products, Pharmaceuticals, Electrotechnical, Computers and electronic equipment, large companies account for over 90% of the sample. In other sectors, although large firms still account for the largest share, there is also a greater concentration of medium-sized firms: this is the case in Fabricated metal products, Chemical Consumer goods, Textiles, textile products, leather and footwear, and the Furniture sector (with shares of 15% or more).

2. Financial KPIs in the 2019-24 period

This section compares the performance of Circular manufacturing firms with the overall performance of the Italian manufacturing sector holding patents (hereinafter referred to simply as 'Manufacturing'), focusing on a number of key economic and financial performance indicators such as turnover, profit margins (EBITDA margin), profitability (ROI and ROE), capitalization and productivity, including both labour productivity (value added per employee) and total factor productivity.

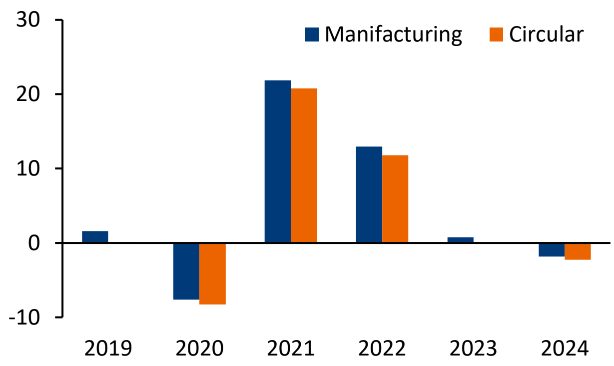
8 The breakdown by size class is calculated using the European Commission's turnover thresholds, with reference to the year 2024. Micro and small firms: up to €10 million. Medium-sized firms: between €10 million and €50 million. Large firms: over €50 million.

The analysis, based on financial statements for 2019–24, will also attempt to outline a profile of the strategic levers adopted by firms, which may help to explain the competitive advantage of Circular enterprises.
Descriptive findings are based on median values of the distribution of financial KPIs, to ensure that results are not unduly influenced by outliers (i.e. firms with financial and economic performance that significantly diverges from the general distribution, often due to extraordinary events, non-recurring transactions or exceptional size). Moreover, the analysis considers the sectoral and size structures of the firms in the sample. Qualitative results will be explored in greater detail in the third section, which is devoted to the econometric approach.

2.1 Revenues

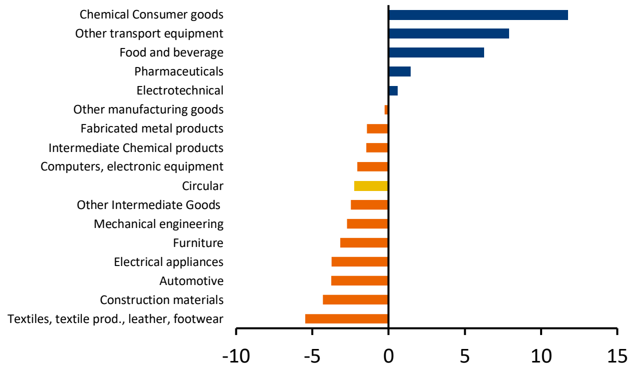
Circular firms benefited from the post-pandemic recovery, achieving impressive turnover results in the 2021–22 period. In 2023–24, however, the onset of the inflationary spiral resulting from the energy crisis caused by the Russia–Ukraine conflict led to a gradual slowdown in demand across supply chains, which in turn resulted in a stabilization of Circular turnover in 2023, and a subsequent decline in 2024 (-2.3%), slightly more pronounced than that recorded by the manufacturing sector as a whole (-1.8%). In the case of Circular enterprises, the 2024 decline appears to be widespread across the main sectors, except for Chemical Consumer goods (+11.8%), Other transport equipment (+7.9%), Food and beverage (+6.3%), Pharmaceuticals (+1.4%) and Electrotechnical (+0.6%).

Fig. 7 – Revenue trend analysis from 2019 to 2024 (% change at current prices, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 8 – CE sample: revenues 2024 vs 2023 (% change at current prices, median values)

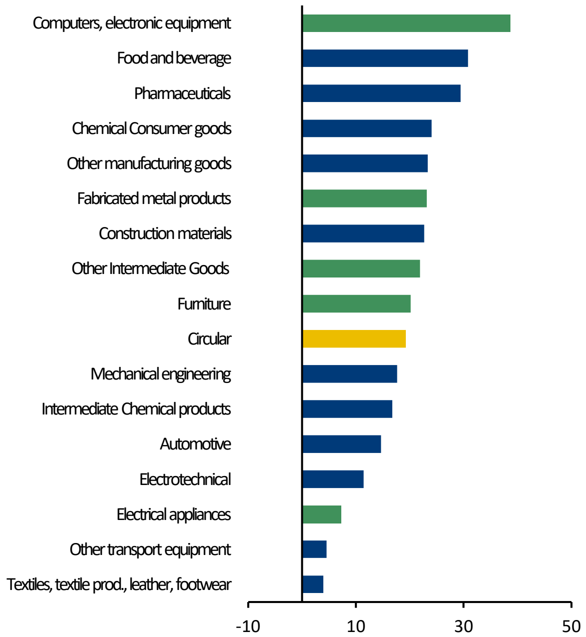


Source: Intesa Sanpaolo Integrated Database (ISID)

However, the results at current prices are influenced by the upward trend in producer prices, which rose sharply in 2021 (+6.2% year-on-year), driven by the rapid post-Covid recovery, and particularly in 2022 (+13.8%) due to inflationary pressures stemming from the energy crisis. Prices then underwent a gradual normalization

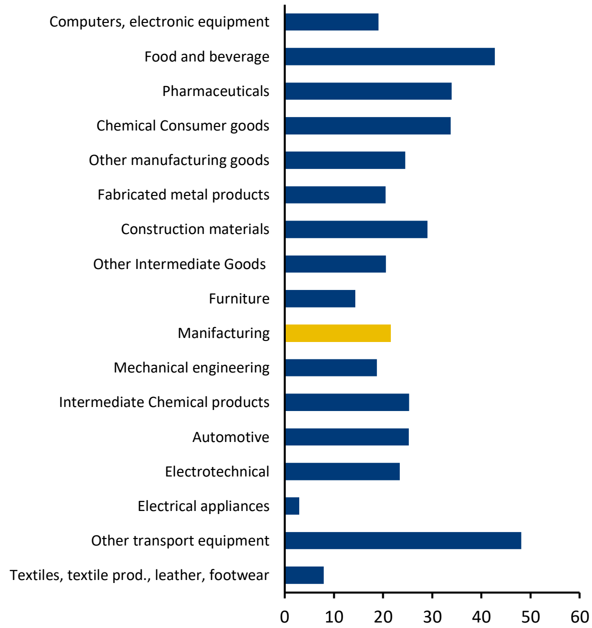
(+1.8% in 2023, -1% in 2024) but remain at high levels. In fact, the 2024 turnover of Circular firms is 19.3% higher than the 2019 level, despite the downsizing experienced during the year.

Fig. 9 – CE sample: revenues 2024 vs 2019 (% change at current prices, median values)



Source: Intesa Sanpaolo Integrated Database (ISID). Note: sectors performing above the manufacturing average are in green

Fig. 10 – Manufacturing sample: revenues 2024 vs 2019 (% change at current prices, median values)



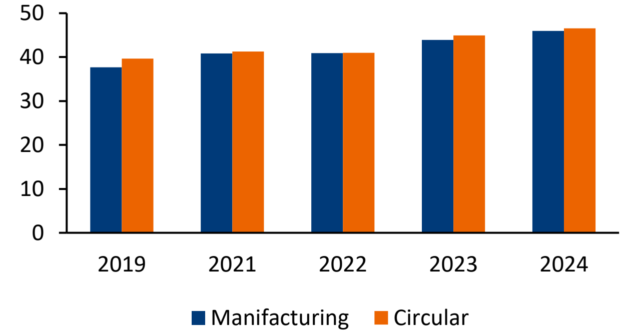
Source: Intesa Sanpaolo Integrated Database (ISID)

2.2 Capitalization of assets

Whilst turnover results provide an immediate reflection of changes in the economic cycle and demand conditions across supply chains, an analysis of financial indicators – and in particular of the balance sheet structure – reveals a more comprehensive picture of the competitive position of companies that have patented innovations in the circular economy field.

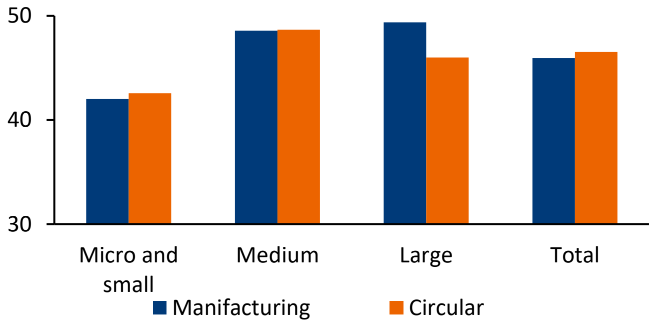
Capitalization of assets (equity as a percentage of total assets) followed a general upward trend between 2019 and 2024, with Circular firms consistently maintaining higher levels than those in the manufacturing sector: (39.6% in 2019, vs 37.7% and 46.5% in 2024, vs 45.9%). This trend towards stronger equity is confirmed by the analysis by size category, apart from large enterprises, where the manufacturing sample instead shows higher levels. Strengthening equity capital is an important factor, since it reflects companies' ability to absorb any external shocks without having to rely excessively on debt, thereby maintaining a balanced budget even during periods of macroeconomic uncertainty.

Fig. 11 – Equity as a % of total assets from 2019 to 2024 (median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 12 – Equity as a % of total assets 2024, by firm size (median values)



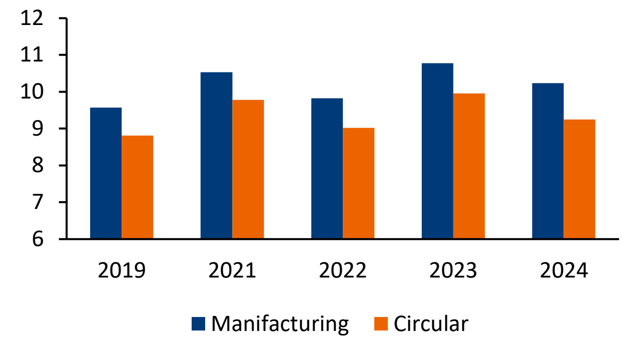
Source: Intesa Sanpaolo Integrated Database (ISID)

2.3 EBITDA margins and profitability indicators

The assets structure of Circular companies also provides an important framework for interpreting changes in profitability indicators. The strengthening of equity, together with the increasing proportion of capitalized assets, has in fact contributed to a change in the composition of invested capital, with potential implications for financial performance.

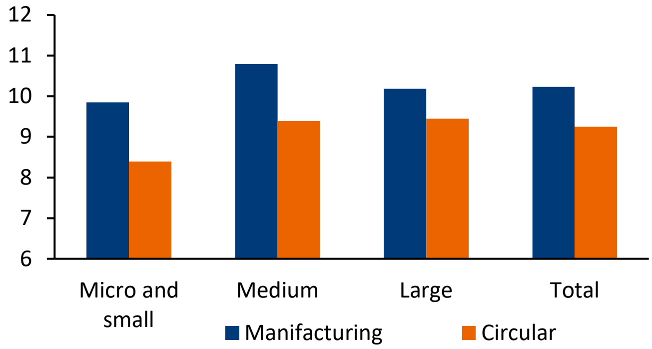
In 2024, **EBITDA margins (Earnings Before Interest, Taxes, Depreciation and Amortization, as a % of Sales)** of Circular firms exceed 9%, showing steady growth compared with 2019 levels, but remain consistently below the median levels of the manufacturing sector, even when comparing companies of the same size. Circular firms have also demonstrated a marked ability to maintain profit margins, even in the 2023–24 period, characterized by strong inflationary pressures following the 2022 energy crisis.

Fig. 13 – EBITDA margins from 2019 to 2024 (%, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 14 – EBITDA margins 2024, by firm size (%, median values)

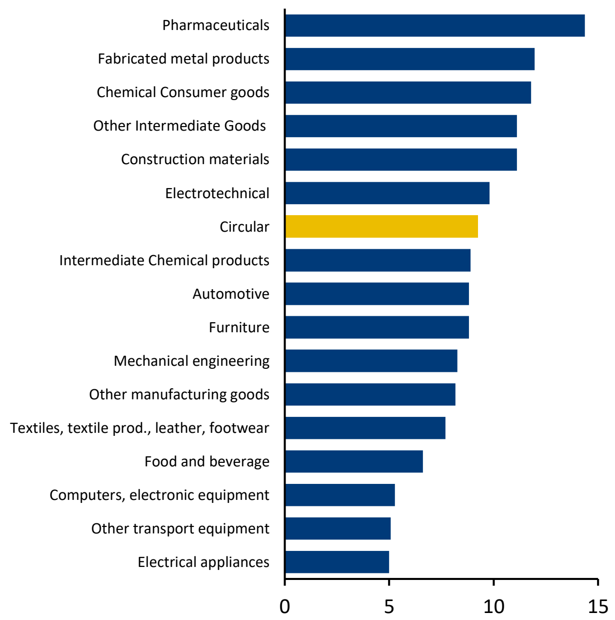


Source: Intesa Sanpaolo Integrated Database (ISID)

There is considerable sectoral variation. The overall 2024 EBITDA margin result (9.2% on a median basis) is in fact heavily influenced by margins in Mechanical

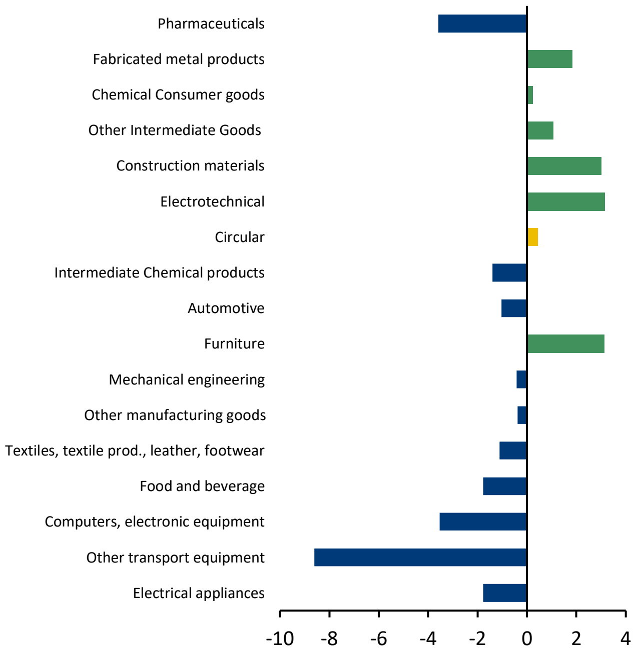
Engineering, the predominant specialization. Several sectors within the CE group are performing well above the median, starting with Pharmaceuticals, with an EBITDA margin of 14.4% in 2024. These are followed by Fabricated metal products (12%), Chemical Consumer goods (11.8%), Other Intermediates and Construction materials (11.1%), and Electrical appliances (9.8%), which rounds off the group of top performers. In terms of growth rates for 2019–24, Fabricated metal products, Chemical Consumer goods, Other Intermediates, Construction materials, and Electrical appliances also stand out, joined by Furniture, where the increase in margins for Circular companies was also made possible through an effective repositioning towards high-end product segments. The sector experiencing the sharpest decline in margins over the 2019–24 period is Other transport equipment, likely due to a revenue structure tied to multi-year contracts which, can make it more difficult to absorb operating costs, particularly during the most challenging phases.

Fig. 15 – CE sample - EBITDA margin 2024 (%, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

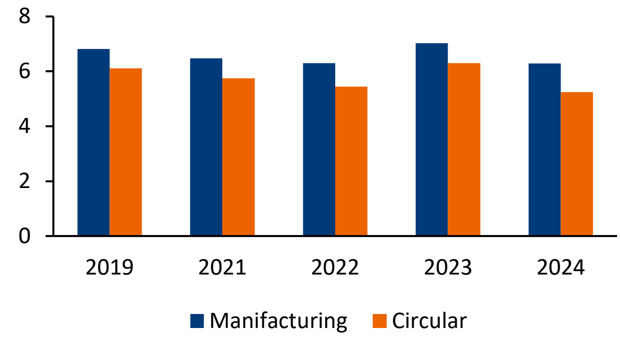
Fig. 16 – CE sample - EBITDA margin: % delta between 2024 and 2019 (median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

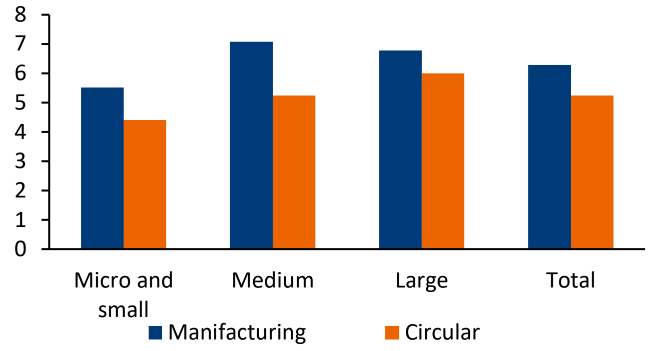
The stability of operating margins is not matched by a similar trend in profitability. In 2024, the return on invested capital measured by **ROI (Return on Investment)**, a key indicator of operational efficiency, stood at 5.2% for Circular firms (median value), down from 6.1% in 2019 and, above all, from the peak of 6.3% reached in 2023. A decline was also observed across the manufacturing sector as a whole, albeit less pronounced. Furthermore, a comparison by company size confirms the existence of a structural gap between the two samples: the circular sample falls below the manufacturing sector's ROI levels across all company sizes, with a marked disparity in the medium-sized enterprise segment, which struggles more to convert invested capital into operating profit (5.2% for medium-sized circular enterprises, compared to 7.1% for their manufacturing counterparts).

Fig. 17 – ROI from 2019 to 2024 (%, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

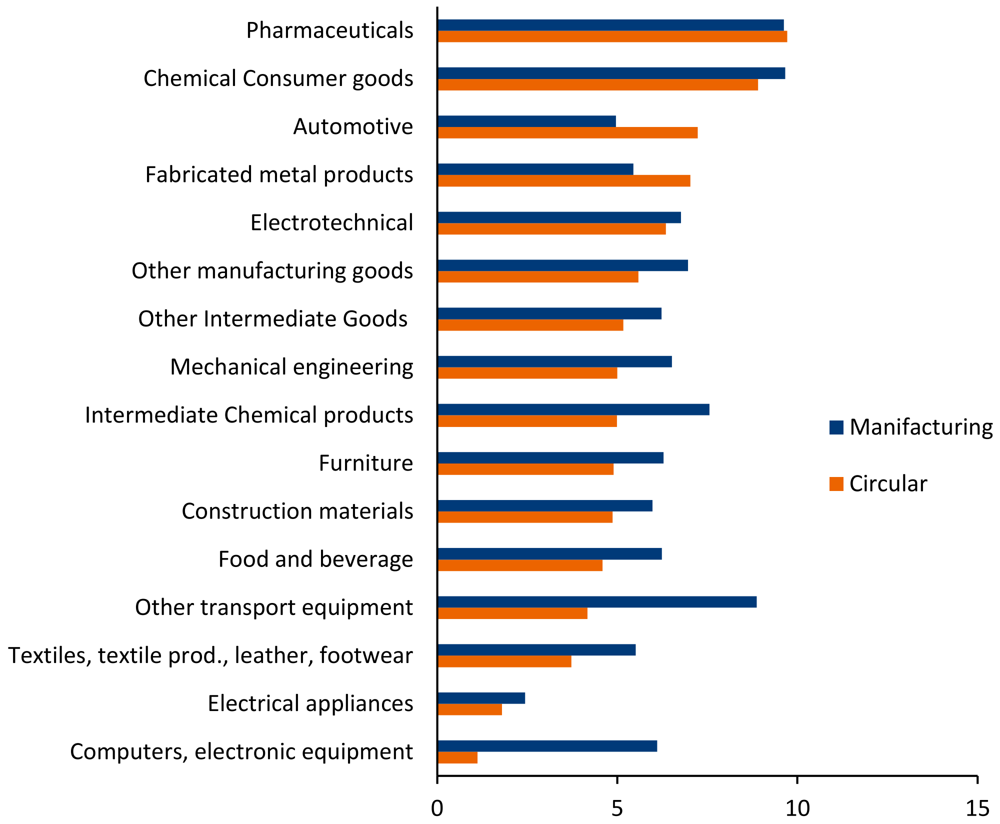
Fig. 18 – ROI 2024, by firm size (%, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

The analysis of ROI by macro-sector also reveals a marked polarization within the Circular sample. Only a small group of sectors ranks above the median, which is once again heavily influenced by the (dominant) Mechanical Engineering sector. A few sectors stand out, in particular Electrotechnical, Fabricated metal products, Automotive, Chemical Consumer goods, Other manufacturing goods and Pharmaceuticals (where the ROI of Circular firms is entirely in line with that of the non-EC manufacturing sample and reflects the sector's great capacity to generate high returns).

Fig. 19 – CE sample - ROI 2024 (%, median values)

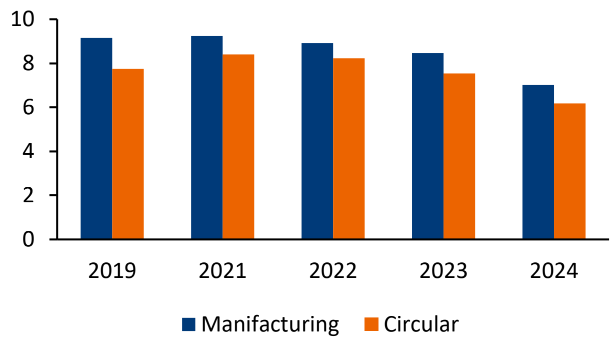


Source: Intesa Sanpaolo Integrated Database (ISID)

In terms of overall profitability, as measured by **ROE (Return on Equity)**, there has also been a gradual decline from the peaks reached in the post-pandemic period. The 2024 level, which stands at 6.2% (median) for Circular firms, is in fact significantly lower than the 2019 levels (7.7%). This trend is not isolated. It is a widespread phenomenon common to both Circular enterprises and the manufacturing sector as a whole. Among the factors that may have influenced this decline, is the rise in the cost of debt recorded during the observation period. The increase in financial costs has likely exerted growing pressure on net profits, reducing the positive effect of financial leverage and contributing to a squeeze in final profitability for shareholders, compared to the previous two-year period.

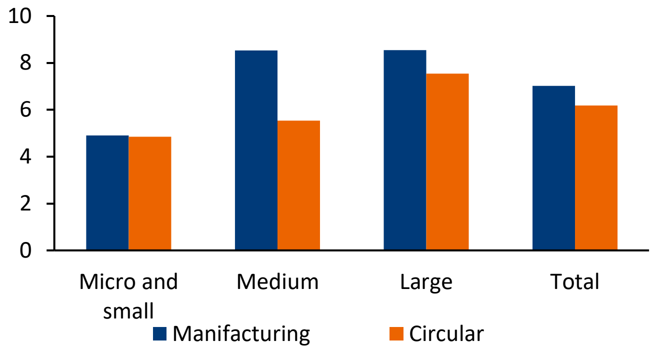
From a size perspective, the analysis reveals a mixed picture: among micro and small enterprises, the level of ROE appears broadly aligned between the Circular sample and the rest of the manufacturing sample, whilst the gap is more pronounced in the medium-sized enterprise segment, in favor of the manufacturing sector.

Fig. 20 – ROE from 2019 to 2024 (%, median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 21 – ROE 2024, by firm size (%, median values)

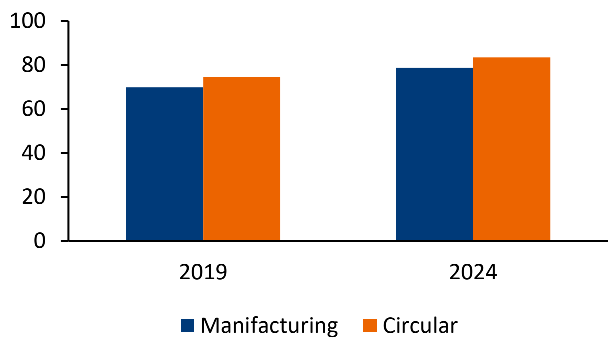


Source: Intesa Sanpaolo Integrated Database (ISID)

2.4 Labor Productivity and Total Factor Productivity

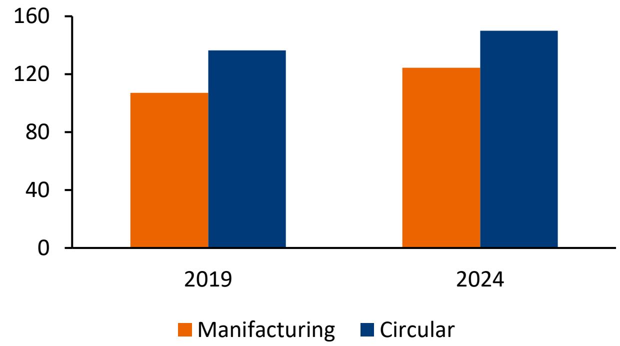
Another key factor in assessing the competitiveness of the Circular sample is **Labour Productivity** (value added per employee, at current prices, calculated from financial statements), which is up compared with 2019 (€83,400 per employee in 2024, up from €74,600 in 2019) and consistently higher than that of the manufacturing sector (where it stands at €78,800 per employee in 2024).
Once again, the median for the Circular cluster is heavily influenced by Mechanical Engineering, a key sector in the sample, where a clear Circular productivity differential emerges. There are also several sectors within the CE group where productivity levels exceed the median, starting with Food and beverage, Automotive, and Furniture. The productivity advantages of Circular firms are preserved even when **Total Factor Productivity (TFP)** is considered, estimated using the method proposed by Levinsohn and Petrin (2003)[9].

Fig.22 – Labour productivity (median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

Fig. 23 – Total Factor Productivity (median values)



Source: Intesa Sanpaolo Integrated Database (ISID)

9 The method developed by Levinsohn and Petrin (2003) estimates total factor productivity (TFP) in presence of correlation between production factors. The approach is an extension of the work by Olley and Pakes (1996).

3. Econometric approach

As already mentioned, the Intesa Sanpaolo dataset allows to go beyond financial data in order to draw up a more advanced strategic and competitive profile of Circular firms.

The information on the strategic levers implemented by companies covers various areas of business operations: from international trademark registration with WIPO (World Intellectual Property Organization, variable *trademarks*) to the acquisition of quality certificates ISO 9001 (variable *quality cert.*), from being owned by multinational companies (*FDI_in*) to investments in foreign markets (*FDI_out*), source Reprint. In addition to patent data identifying Circular companies, the dataset includes a broad overview of the green strategies implemented by companies, including environmental certifications (*environmental cert.*)[10] and installation of renewable energy sources (variable *renewable energy*)[11].

Moreover, additional information is available on export activity (*export*) and on the belonging of firms to a corporate group (variable *corporate group*)[12]. Finally, the composition of the board of directors (source CERVED) provides an overview of gender (relevance of women in the board, at least 50%, variable *50%women_board*) and inclusion issues (presence of people under 40 in the board, variable *under40_board*, which are generally more open to change, especially in the field of technology).

Descriptive statistics highlight that Circular firms are strictly focused on sustainability and internationalization. Specifically, it is possible to observe a wider uptake of quality and environmental certifications. This approach is a step towards the new European directive on non-financial reporting (CSRD, Corporate Sustainability Reporting Directive), which ensures easier access to credit and to global value chains. Moreover, a wider adoption of renewable energy systems emerges from data. In addition, Circular firms show a strong propensity to export,

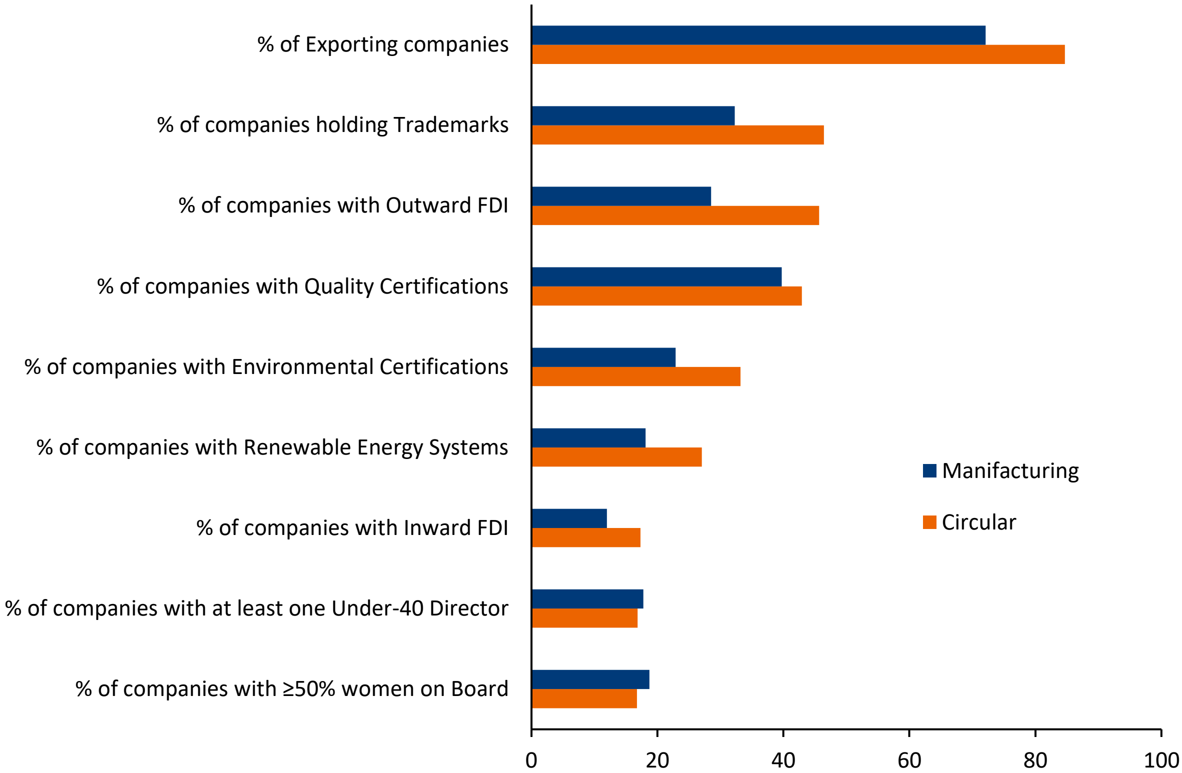
10 We considered environmental certifications ISO 14001, EMAS (Eco-Management and Audit Scheme) certifications and FSC (Forest Stewardship Council) international certifications which are specific to the forest sector and wood and non-wood products derived from forests, and those relating to organic production, which are specific to the food and beverage sector.

11 Companies that have installed at least one renewable energy system for the self-generation of electricity, by relying on incentives provided by the GSE (Energy Services Operator) under the Energy Account scheme, GRIN (Incentive Recognition Management) certificates, or the Renewable Energy Sources (RES) scheme for electricity. It is possible that the actual proportion of firms within our sample that have installed renewable energy systems is underestimated. Indeed, many firms may have installed grid-connected photovoltaic systems without making use of GSE incentives.

12 A corporate group is a collection of legally independent companies that are subject to the dominant influence of a single parent company (holding company), which exercises centralized control. This structure, found in 99% of large industrial firms, enables the optimization of resources, the sharing of risks and the coordination of activities.

underpinned not only by an extensive sales network, but also by the protection of intellectual property through globally registered trademarks, a solid international presence through outward foreign direct investment (*FDI_out*), and a strong ability to attract foreign capital and partnerships (*FDI_in*).
However, the analysis also highlights areas for improvement, especially regarding generational renewal and gender diversity. Indeed, increasing the number of young people and women in senior positions remains a goal that needs to be further developed in order to bring governance fully into line with the highest international standards.

Fig. 24 – Qualitative Analysis: competitive advantages of CE firms



Source: Intesa Sanpaolo Integrated Database (ISID)

Econometric analysis can validate the qualitative findings that have emerged so far. As a first step, a *probit* analysis accounts for the strategic levers implemented by firms together with the scale-related factors (*small*, *medium* and *large* dummies) and the sectoral effects (μ_j) that might have conditioned the belonging of firms (i) to the Circular cluster:

$$circular_i = \beta_0 + \beta_1\, trademarks_i + \beta_2\, quality\ cert._i + \beta_3\, environmental\ cert._i + \beta_4\, renewable\ energy_i + \\ + \beta_5\, ide\_IN_i + \beta_6\, FDI\_out_i + \beta_7\, export_i + \beta_8\, corporate\ group_i + \beta_9\, under40\_board_i + \\ + \beta_{10}\, 50\%women\_board_i + \beta_{11}\, small_i + \beta_{12}\, medium_i + \beta_{13}\, large_i + \mu_j + u_i$$

Table 1 reports the *marginal effects* after probit and provides confirmation of most of the messages already discussed so far: circularity is often associated with an advanced strategic profile. Results highlight the presence of a positive and significative correlation (p<0,1%) between the installation of renewable energy systems, outward foreign direct investment (*FDI_out*) and membership of the Circular group. Specifically, investing in renewable energy sources increases by 3% the likelihood of being classified Circular, whilst making FDI in foreign markets increases the same likelihood by 2.9%. Only marginally significant (p<5%) the correlation with trademarks.

The correlation is not significant at all for the other variables: *FDI_in*, quality and environmental certifications, corporate group, and export. In fact, even in descriptive terms, this latter characteristic emerges as a strategy which is widely adopted by both circular and non-circular firms in the sample.

A significant size effect is present. The probability of belonging to the Circular cluster increases for medium-to-large firms (with a turnover exceeding €10 million). This pattern suggests that circular innovation, at least the one captured by patents, requires technological capabilities, investments and organizational structures which are more typical of medium-sized and large firms.

Looking at the characteristics of company boards, only a weakly significant (and negative) effect emerges between membership of the Circular group and the presence of young people (under 40). Given that patenting related to the circular economy experienced strong growth until the late 2000s, before stabilizing, it is not plausible to assume that the age and gender characteristics of directors – drawn from a recent snapshot of the board (year 2023) – have influenced companies' propensity to introduce Circular technologies. Rather, they should be interpreted in the opposite light, namely in terms of the ability of Circular firms to renew themselves and focus more on inclusion. The negative sign of the marginal effect and its low significance are consistent with a descriptive analysis showing a slightly higher proportion of under-40s among non-circular firms in the sample (18.6%) compared to circular firms (16.5%), although in the mechanical engineering sector – which is the predominant sector – the proportions of under-40s in the two clusters are very similar.

Tab. 1 – Marginal Effects after probit: determinants of the probability to belong to the cluster of circular firms

	Marginal effect	Standard error
Trademarks	0,022*	0,009
Quality certifications	-0,003	0,009
Environmental certifications	0,011	0,010
Renewable energy	0,033***	0,010
FDI_in	0,019	0,012
FDI_out	0,029***	0,010
Export	-0,024	0,019
Corporate group	0,006	0,010
Under40_board	-0,021*	0,011
50% women_board	0,014	0,011
Small firms	0,024	0,015
Medium firms	0,054***	0,016
Large firms	0,100***	0,019
Sectoral effects	added	

Number of observations: 6.707
Significance level *** 0,001 ** 0,01 * 0,05
Dimensional effects: micro firms represent benchmark in estimation

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As a final research step, we investigated the impact of Circular innovation on productivity growth, where positive differentials emerge from descriptive statistics.

A panel approach is not the preferred way because productivity is a structural phenomenon which is more closely linked to medium- to long-term changes taking place within firms than to the economic cycle. Productivity gains are stronger when comparing periods that are far apart in time – at least five years apart – rather than year-on-year trends. Moreover, circular technologies show discontinuous patterns (a boom in the early 2000s and a slowdown in terms of growth rates in the most recent years, as outlined in the paper by Manera and Quatraro (2025) which is the source of CE patents used in this analysis. In light of this, it is preferable to place greater emphasis on aggregate statistics on innovation: in our specific case, circular firms were identified by summarizing patent demands filed between 1998 and 2023.

A *Heckman selection model* has been selected, which allows for the management of both cumulative changes (2019–24) in the dependent variable 'productivity' and the presence of potential unobservable factors that may have influenced the classification of firms into the circular cluster[13]. Specifically, the following two alternative definitions of productivity were considered:

- *Labour Productivity* (delta 2019-24);
- *Total Factor Productivity* (delta 2019-24)[14].

The structure of the model can be summarized as follows:

$$\begin{aligned} delta\_producitivity\_2019\text{-}24_i = {} & \beta_0 + \beta_1\, circular_i + \beta_2\, trademarks_i + \beta_3\, quality\ cert._i + \\ & + \beta_4\, environmental\ cert._i + \beta_5\, renewable\ sources_i + \beta_6\, FDI\_IN_i + \\ & + \beta_7\, FDI\_OUT_i + \beta_8\, export_i + \beta_9\, corporate\ group_i + \beta_{10}\, under40\_board_i + \\ & + \beta_{11}\, 50\%women\_board_i + \beta_{12}\, small_i + \beta_{13}\, medium_i + \beta_{14}\, large_i + \mu_j + u_i \end{aligned}$$

$$\begin{aligned} circular_i = 1\, (& \beta_0 + \beta_1\, trademarks_i + \beta_2\, quality\ cert._i + \beta_3\, environmental\ cert._i + \beta_4\, renewable\ sources_i + \\ & + \beta_5\, FDI\_in_i + \beta_6\, FDI\_out_i + \beta_7\, export_i + \beta_8\, corporate\ group_i + \beta_9\, under40\_board_i + \\ & + \beta_{10}\, 50\%women\_board_i + \beta_{11}\, small_i + \beta_{12}\, medium_i + \beta_{13}\, large_i + \mu_j + w_i > 0) \end{aligned}$$

$$Cov\,(u_i\,;\,w_i\,) = \rho$$

13 Heckman's selection model (1979) is a statistical approach used in econometrics to correct for selection bias, which occurs when data are incomplete due to a non-random selection process. It is a two-stage model that first estimates the selection equation (cluster membership determined by the treatment variable, in our specific case investment in circular technologies) and then the outcome equation (the relationship between performance variables and determinants, including the circular treatment variable). This process allows for more accurate and reliable estimates of the parameters, particularly when there are unobservable variables.

14 In the econometric model, we consider delta logs (2019-24) of productivity.

In addition to the qualitative variables described above, the model includes the set of dummy variables μ_j, which captures sectoral patterns (2-digit Ateco 2022 classification) of productivity growth, and the *small*, *medium* and *large* variables, which capture size effects (relative to the benchmark cluster of micro-enterprises)[15]. Econometric estimates highlight a positive and marginally significant effect (p<5%) of the Circular innovation on productivity dymanics over the period 2019–24: the estimated coefficient for the dummy variable Circular is 0.144 for labour productivity and 0.141 for total factor productivity. The significant coefficient of the *Hazard Lambda* or *Inverse Mills Ratio* implies the presence of a firm self-selection mechanism, which cannot be identified using a simple probit analysis (step 1) and justifies the adoption of a two-step Heckman approach.

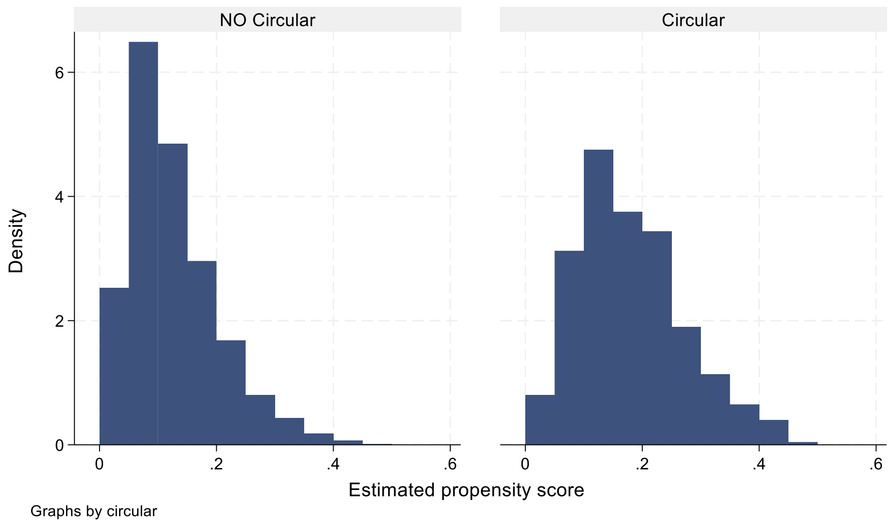
The causal relationship between the Circular cluster and productivity gains is significant despite the prominent role played by firms' productivity levels in the baseline year 2019 and the presence of significant scale effects. Specifically, there is a negative and significant correlation between the 2019 productivity level and the productivity gain over the following five-year period (amounting to -0.433 for labour productivity and -0.447 for TFP): medium-to-high levels of productivity in 2019 are associated with a less pronounced change in productivity between 2019 and 2024. Furthermore, compared with the benchmark cluster of micro-enterprises, SMEs and, above all, large enterprises exhibit more pronounced productivity gains, both in terms of labour productivity and in terms of TFP.

To test the robustness of our results, a further selection of non-Circular companies has been carried out based on *propensity score matching* techniques[16]. Specifically, by adopting a matching approach of the *nearest neighbor* type, with r*eplacement* of observations, the control sample has been scaled down to around 2,500 firms with characteristics similar to those belonging to the Circular cluster - in terms of size, sector of specialization and the use of strategic levers, as already identified in the descriptive and probit analyses. Fig. 25 shows the overlap between the two subsamples of Circular companies and non-Circular companies with patents.

15 Size categories have been calculated based on the European Commission's turnover thresholds. See footnote 13.

16 For a discussion of the use of propensity score matching techniques to improve the overlap between the control sample and the sample of treated firms, see the papers by Dehejia and Wahba (1999, 2002).

Fig. 25: distribution of estimated propensity scores, non-Circular and Circular samples



Once adjusted for confounding factors, the causal relationship between Circular patents and changes in productivity loses significance, suggesting that the previous findings were likely driven more by the sample structure – namely, the inclusion of control firms that were not entirely comparable to Circular firms in strategic and competitive terms (even though they were similar in terms of innovation and production specialization).

The absence of a direct causal link between innovation in the circular economy and changes in productivity does not in itself invalidate the previous analysis. It rather helps to put the analysis into the right perspective. Supporting circularity means, by the way, helping firms on their growth paths towards advanced production processes: not only greater technological intensity but also better work organization and attention to other key aspects of sustainability and digitalization, which can trigger a virtuous cycle of resilience, particularly during periods of greatest economic fragility.

Results: Labour Productivity

Tab. 2 – Estimates from "Heckman Selection Model – Heckit": overall sample, dependent variable Labour Productivity (delta 2019-24)

	Selection equation		Outcome equation	
	Coefficient	Standard error	Coefficient	Standard error
Circular (treatment variable)			0.144*	0.064
Trademarks	0.117*	0.046	-0.032*	0.013
Quality certifications	-0.011	0.043	-0.008	0.012
Environmental certifications	0.060	0.051	-0.023	0.013
Renewable energy	0.168***	0.048	-0.006	0.013
FDI_in	0.119	0.062	-0.064***	0.019
FDI_out	0.153***	0.050	-0.044***	0.013
Export	-0.098	0.093	0.015	0.021
Corporate group	0.039	0.050	-0.019	0.013
Under40_board	-0.100	0.054	0.026	0.015
50% women_board	0.076	0.055	0.001	0.014
Small firms	0.137	0.092	0.105***	0.027
Medium-size firms	0.287***	0.097	0.212***	0.027
Large firms	0.512***	0.109	0.318***	0.034
Log Labour Producitvity_2019			-0.433***	0.029
Sectoral dummies	added		added	
Hazard Lambda			-0.091	0.035
Rho			-0.203	0.078
Sigma			0.445	0.011
Wald test of indep. eqns. (rho=0)				0.066
Prob > chi2				

Number of observations: 6,318
Significance levels *** 0,001 ** 0,01 * 0,05
Dimensional effects: micro firms represent benchmark in estimation

Tab. 3 – Estimates from "Heckman Selection Model – Heckit": subsample of matched firms, dependent variable Labour Productivity (delta 2019-24)

	Selection equation		Outcome equation	
	Coefficient	Standard error	Coefficient	Standard error
Circular (treatment variable)			0.132	0.114
Trademarks	0.110	0.063	-0.046	0.020
Quality certifications	0.054	0.057	-0.007	0.017
Environmental certifications	0.164	0.071	-0.043*	0.020
Renewable energy	0.409***	0.066	-0.011	0.025
FDI_in	0.366***	0.083	-0.052	0.033
FDI_out	0.164*	0.070	-0.025	0.019
Export	-0.168	0.117	0.034	0.028
Corporate group	-0.083	0.068	-0.009	0.021
Under40_board	0.284**	0.074	-0.014	0.025
50% women_board	0.334***	0.070	-0.011	0.024
Small firms	0.137	0.115	0.079	0.043
Medium-size firms	0.352***	0.128	0.177***	0.048
Large firms	0.382*	0.150	0.295***	0.053
Log Labour Productivity_2019			-0.412***	0.030
Sectoral dummies	added		added	
Hazard Lambda			-0.092	0.069
Rho			-0.211	0.158
Sigma			0.433	0.014
Wald test of indep. eqns. (rho=0)				0.235
Prob > chi2				

Number of observations: 3,178
Significance levels *** 0,001 ** 0,01 * 0,05
Dimensional effects: micro firms represent benchmark in estimation

Results: Total Factor Productivity

Tab. 4 – Estimates from "Heckman Selection Model – Heckit": overall sample, dependent variable Total Factor Productivity TFP (delta 2019-24)

	Selection equation		Outcome equation	
	Coefficient	Standard error	Coefficient	Standard error
Circular (treatment variable)			0.141*	0.056
Trademarks	0.109	0.056	-0.028	0.015
Quality certifications	0.024	0.051	-0.002	0.014
Environmental certifications	-0.035	0.063	-0.002	0.016
Renewable energy	0.162***	0.059	0.002	0.015
FDI_in	0.072	0.074	-0.056*	0.023
FDI_out	0.156	0.060	-0.032*	0.016
Export	-0.126	0.122	0.024	0.024
Corporate group	0.001	0.058	-0.007	0.015
Under40_board	-0.171**	0.068	0.013	0.018
50% women_board	0.067	0.065	-0.013	0.016
Small firms	0.127	0.103	0.235***	0.030
Medium-size firms	0.297***	0.108	0.429***	0.036
Large firms	0.517***	0.125	0.662***	0.047
Log TFP_2019			-0.447***	0.030
Sectoral dummies	added		added	
Hazard Lambda			-0.084	0.029
Rho			-0.191	0.066
Sigma			0.440	0.014
Wald test of indep. eqns. (rho=0)				0.064
Prob > chi2				

Number of observations: 4,599
Significance levels *** 0,001 ** 0,01 * 0,05
Dimensional effects: micro firms represent benchmark in estimation

Tab. 5 – Estimates from "Heckman Selection Model – Heckit": subsample of matched firms, dependent variable Total Factor Productivity TFP (delta 2019-24)

	Selection equation		Outcome equation	
	Coefficient	Standard error	Coefficient	Standard error
Circular (treatment variable)			0.025	0.128
Trademarks	0.109	0.078	-0.035	0.024
Quality certifications	0.089	0.069	-0.004	0.021
Environmental certifications	0.097	0.090	-0.001	0.025
Renewable energy	0.392***	0.081	0.007	0.027
FDI_in	0.366	0.101	-0.018	0.037
FDI_out	0.176*	0.086	0.004	0.023
Export	-0.219**	0.154	0.052	0.035
Corporate group	-0.076	0.080	-0.010	0.023
Under40_board	0.218**	0.092	-0.013	0.028
50% women_board	0.314***	0.082	-0.007	0.027
Small firms	0.093	0.119	0.237***	0.045
Medium-size firms	0.308**	0.136	0.422***	0.054
Large firms	0.291	0.166	0.654***	0.065
Log TFP_2019			-0.431***	0.033
Sectoral dummies	added		added	
Hazard Lambda			-0.027	0.074
Rho			-0.064	0.177
Sigma			0.420	0.017
Wald test of indep. eqns. (rho=0)				0.064
Prob > chi2				

Number of observations: 2,306
Significance levels *** 0,001 ** 0,01 * 0,05
Dimensional effects: micro firms represent benchmark in estimation

Conclusions

The paper has shown that circularity, measured in terms of patents in the circular economy field, is associated with a more advanced strategic and competitive profile among firms, in various respects, ranging from internationalization (via exports, membership of multinational groups or registration of trademarks on global markets) to a focus on quality and sustainability (through the acquisition of certifications and the installation of renewable energy systems).

These are development pathways with significant implications for companies' economic and financial performance. It is no coincidence that the analysis of financial statement data for 2019–24 has highlighted the excellent resilience of Circular enterprises in terms of profit margins, even in a context characterized by strong cost pressures and instability in global value chains. Furthermore, the evolution of Circular firms in terms of capitalization and productivity has been particularly significant.

This constitutes important empirical evidence for calibrating future interventions (i.e. business support tools and investment programs) that can trigger a virtuous cycle of growth for the national economy. Looking ahead, the real challenge will not merely be to survive uncertainty, but to use financial strength to drive change, transforming the constraints of sustainability and digitalization into levers for further competitive advantage.

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