Journal of Environmental Management 337 (2023) 117726

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Are circular economy strategies economically successful? Evidence from a longitudinal panel

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A R T I C L E I N F O

Keywords:
Circular economy
Economic performance
Cost of debt
Tobin's Q
Circular economy metric
Circular strategies

A B S T R A C T

While the Circular Economy (CE) is considered a critical tool for addressing environmental degradation, its economic consequences have not received much attention yet. This study fills this gap by investigating the effect of CE strategies on key corporate profitability indicators, debt financing and stock market valuation. Our analysis focuses on a global sample of listed companies over the 2010–2019 period, which allows us to document how CE strategies have evolved over time and regions. To assess the impact of CE strategies on corporate financial measures, we construct multivariate regression models which incorporate a CE score to capture the overall corporate CE performance. We also analyze single CE strategies. Results suggest that implementing CE strategies improves economic returns and is rewarded by the stock market. Creditors, instead, started penalizing firms with worse CE performance only after 2015, the year of the Paris Agreement. Eco-design, take-back and recycling systems, and waste reduction strategies play a major role in increasing operational efficiency. These findings encourage companies and capital providers to direct investments toward CE implementation, with beneficial effects on the environment. From a policymaking perspective, they show that the CE can benefit not only the environment but also the economy.

1. Introduction

Since the 1987 Brundtland Commission advanced the concept of sustainable development (Brundtland, 1987), the economic system has been striving to turn this idea into reality and decouple economic growth from environmental degradation. In this scenario, the circular economy (CE) model has gained attention as a critical tool for fostering this transition and helping achieve this objective (Lieder and Rashid, 2016; Rossi and Bertassini, 2020; Nikolaou and Tsagarakis, 2021).

A CE seeks to disconnect economic development from finite resources by introducing closed resource loops (Korhonen et al., 2018). In the CE, the value of products, materials, and resources is maintained as long as possible by extending their useful life and returning them to the product cycle at the end of their use (Stahel, 1994). This minimizes new resource extraction and the generation of waste (Korhonen et al., 2018; Rosa et al., 2019). Literature suggests that by 2050 ambitious CE goals could lead to a drop in CO2 emissions by 55.3% (Aguilar-Hernandez et al., 2021). In addition, shifting from primary to secondary materials at the global level could reduce primary material use by 27% for metals and 8% for nonmetallic minerals (OECD, 2021). The CE approach could effectively bring positive consequences for air, land, and water pollution, and could have beneficial effects on human health (OECD, 2021). Meanwhile, it could create new jobs and increase a country's GDP (Aguilar-Hernandez et al., 2021), thus determining a "win–win–win" situation in the macroeconomic, social, and environmental domains.

Governments indeed consider the CE a strategic tool for climate change mitigation and economic resilience (Khanna et al., 2022; Domenech and Bahn-Walkowiak, 2019). Japan was the first country to enact CE-related legislation in 2000 (Ministry of the Environment, 2000). The European Union (EU) adopted its first "Circular Economy Action Plan" in 2015 (European Commission, 2015). China is also promoting the CE, although mainly limited to the concept of efficiency (People's Republic of China, 2008). The United States of America (USA), instead, has not yet taken any specific initiative in this field.

Empirical research has widely demonstrated the benefits of CE strategies on the environment (Bjørnbet et al., 2021; Rossi and Bertassini, 2020), product design (Bocken et al., 2016), production processes (Panchal et al., 2021), and supply chain management (Barros and Salvador, 2021; Lüdeke-Freund et al., 2019). On the contrary, the economic implications of CE strategies at a firm level have been poorly

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https://doi.org/10.1016/j.jenvman.2023.117726
Received 29 January 2023; Received in revised form 5 March 2023; Accepted 9 March 2023
Available online 16 March 2023

investigated (Mazzucchelli et al., 2022; Blasi et al., 2021).

The purpose of this study is to fill this gap by investigating whether implementing CE strategies brings consistent economic benefits to companies. This issue is relevant under many aspects. From a corporate perspective, a beneficial impact of CE strategies in terms of higher profitability, lower cost of capital and higher stock market valuation would encourage company managers to undertake such strategies, with a positive contribution to the environment. From a capital providers' perspective, it would qualify CE strategies as more promising or less risky than linear ones. Consequently, capital flows could be expected to redirect towards greener investments, thus supporting the transition to a more sustainable economy. From a policymaking perspective, a beneficial economic effect of CE strategies would highlight that the CE is not only a tool for mitigating climate change but also an opportunity for the economy.

The scope of our analysis is very broad compared to most studies which employ single country, cross-sectional data, a looser definition of CE, or offer a partial vision of economic performance. To perform our study, we first build a measure of circularity that captures the extent to which a company introduces CE strategies. Unlike prior research, we focus on a very stringent definition of a circular economy (Nobre and Tavares, 2021) that catches the very essence of it. To assess the economic and financial impact of CE strategies, we adopt a wide range of measures. We use both accounting-based profitability ratios, which are core to corporate creditworthiness assessment (Altman et al., 2017; Beaver, 1968), and stock market valuations to gain a forward-looking view of corporate performance and risk (Delmas et al., 2015; Fan et al., 2017). Accordingly, we analyze the impact of CE strategies on different measures of profitability, operational efficiency, debt financing, and stock market valuation. Finally, we base our analysis on a global sample of listed companies operating in the mining, manufacturing utilities and construction sectors over the 2010–2019 period. This choice allows us to provide relevant insights into how single CE strategies have evolved, for some of the most polluting sectors, over time (for instance, before and after the Paris Agreement) and across regions. To the best of our knowledge, this is the first study conducted in this area on a global scale and considering both accounting and market performance indicators.

From an academic standpoint, our research contributes to the nascent literature seeking evidence on the possibility that firms could improve their economic performances through the adoption of CE practices. Our findings reveal that a company's proactive behavior toward a circular transition generates positive economic returns. This evidence is of critical importance since companies are motivated to embrace the new economic paradigm if they also improve their economic and financial position. Our analysis also shows that capital providers look at the CE as a promising strategy or a less risky practice compared to a linear model. Firms with better CE performances are rewarded by the stock market with higher equity values, and since 2015 have been charged a lower interest rate. This evidence highlights the potential for the capital market to contribute effectively to the transition.

We also find that the Paris Agreement, signed in 2015, marks a turning point around which all investors have become more aware of the strong commitment that policymakers have taken to fight climate change. In 2015, the European Commission also issued the Action Plan on Circular Economy. The positive effect of the Paris Agreement (and, arguably, the EU Action Plan on Circular Economy) in terms of lower cost of debt and higher stock market values for companies with better CE performances, suggests that public policies can play a crucial role in making investors incorporate environmental risks into their investments. From a public policy perspective, our study finally shows that CE strategies can benefit not only the environment but also the economy.

The remainder of this paper is organized as follows. Section 2 reviews the related literature and develops the research hypotheses. Section 3 presents the data and methodology employed in this study, and Section 4 discusses the results of the data analysis. Section 5 concludes the study.

2. Literature review and hypothesis development

Academic literature extensively shows that the adoption of circular practices represents an important opportunity for changing the business model of organizations (Lewandowski M., 2016; Lüdeke-Freund et al., 2019) by reducing their dependence on finite resources, lowering the environmental burden of their operations, and shortening the value chain (e.g., Gusmerotti et al., 2019; Barros and Salvador, 2021; Lüdeke-Freund et al., 2019).

Following the seminal work of Stahel (1994), a significant number of studies on the CE have focused on the reuse of goods and recycling of materials. Karali and Shah (2022), for instance, find that end-of-life materials could supply approximately 37% of the total material demand from electric vehicles by 2040 (58% by 2050), as well as 45% of the total material demand from battery energy storage systems and wind turbines by the same year (81% for the former and 96% for the latter by 2050). Other studies suggest that product design is also key to increase resource efficiency while minimizing emissions (Lewandowski M., 2016; Mendoza et al., 2017). Finally, a few studies have pointed out the benefits of co-creation and take-back systems in terms of waste being transferred back upstream to be re-processed (e.g., Lüdeke-Freund et al., 2019; Barros and Salvador, 2021; Salvador et al., 2021).

Research on the economic effects of CE strategies is, instead, still very scarce. Moreover, it is mainly based on cross-sectional data, or single countries or limited aspects of economic performance. Table 1 lists the articles available on the topic.

Mazzucchelli et al. (2022) focus on large-sized manufacturing firms operating in Italy, finding higher levels of reputation and better economic performances for those engaging in CE practices. Along the same lines, Horbach and Rammer (2020) suggest a positive impact of circular process innovation on sales growth for a group of German companies. Other studies examine the relationship between circularity and firm growth in small and medium-sized enterprises (SMEs), finding that certain strategies, such as eco-design (Demirel and Danisman, 2019) or resource efficiency (Majid et al., 2020), produce increasing economic returns. Similarly, Blasi et al. (2021) find that communicating CE-related initiatives improves economic performances, measured in terms of return on assets, of a sample of Italian manufacturing SMEs. Zara et al. (2021a) highlight that the circular business model is considered a de-risking factor by equity holders, especially in periods of financial markets' instability, such as the COVID-19 pandemic (Zara et al., 2021b). In contrast, Antonioli et al. (2022) fail to provide evidence of better economic performance for a sample of Italian firms adopting CE-related innovations.

Unlike these studies, our analysis adopts a longer term and geographically broader perspective on the effects of CE strategies, focusing on a sample of worldwide listed firms operating in highly polluting sectors (Alogoskoufis et al., 2021), which we observe over ten years. Moreover, it considers a wider set of economic and financial indicators, which allows us to adopt a more comprehensive view of the impact of CE strategies both on corporate profitability and its access to capital. Considering that the transition toward a CE model can appear more attractive to businesses if they perceive it as an opportunity for higher positive economic outcomes (Lieder and Rashid, 2016), we investigate whether organizations that are more proactive in the transition to a more circular economy are more likely to improve their economic performances. In other words, we examine whether higher profitability ratios and better conditions in accessing capital are among the benefits (not the drivers) of the CE strategies.

Based on prior literature, we pose our first research question as follows:

Table 1
Research on the economic impact of circular economy strategies at a firm level.

Author(s) (Year)	Region	Sector	Period	Circular economy strategies	Economic indicators	Significant results
Demirel and Danisman (2019)	Europe	Manufacturing, construction, retail, utilities and services	2016	Circular eco-innovations	Firm growth	Positive impact of eco-design, no impact of water and energy efficiency and renewable energy
Horbach and Rammer (2020)	Germany	Manufacturing and services	2014–2016	CE product and process innovations	Firm growth, Financial standing and Labour productivity	CE innovation brings higher sales and employment growth
Majid et al. (2020)	Europe	Manufacturing, construction, retail, utilities and services	2012, 2013, 2015 and 2018	Resource efficiency actions	Annual turnover	Positive impact of certain resource efficiency actions
Blasi et al. (2021)	Italy	Manufacturing	2019	CE web communication	Economic performance (ROA)	Low- and medium- performing SMEs highly benefit from CE-focused web communication
Zara et al. (2021a)	Europe	Manufacturing, construction and utilities	2013–2017	Circularity Score (level of circular business practices)	Equity risk	Lower exposure risk for companies with a higher Circularity Score
Zara et al. (2021b)	Europe	Manufacturing, construction and utilities	2019–2020	Circularity Score (level of circular business practices)	Market-based risk (Stock return volatility)	Lower exposure risk for companies with a higher Circularity Score also when a shock occurs
Antonioli et al. (2022)	Italy	Manufacturing	2019	CE product, process and organizational innovations	Revenues and Production costs	CE innovations are scarcely related to revenues and to production costs
Mazzucchelli et al. (2022)	Italy	Manufacturing	2020	CE practices: waste treatment, reduction and recycling	Brand reputation, Profit and Operational performance	The relationships between waste treatment, recycling practices, and financial performance are mediated by brand reputation, while reduction practices have a direct effect

Hypothesis 1. (H1): Firms with better performance in the CE increase their operational efficiency and profitability.

Existing literature also demonstrates that a firm's exposure to carbon risk or environmental, social and governance (ESG) performance is reflected in its lending conditions. Firms with lower emissions or better ESG performance benefit from a lower cost of debt (Gao and Wan, 2022; Palea and Drogo, 2020; Eliwa et al., 2021). Similarly, we assume that adopting CE strategies can lead to more favorable conditions for debt financing. Accordingly, we formulate the following hypothesis:

Hypothesis 2. (H2): Firms with better performance in the CE pay a lower cost of debt.

An extensive stream of literature employs market-based measures to reflect the capital providers' perception of a firm's future economic performance related to its efforts toward environmental sustainability (Misani and Pogutz, 2015; Hassan and Romilly, 2018; Nishitani and Kokubu, 2012). For instance, Delmas et al. (2015) as well as Palea and Santhià (2022) find that the market rewards companies which are already on a path toward cleaner production methods and thereby less exposed to transition risks. Similarly, Zhou et al. (2022) note that ESG performance improvements are reflected in a company's market value. Iwata and Okada (2011) and Palea and Santhià (2022) further highlight that a decrease in GHG emissions increases the value of intangible assets. Against this background, we posit that a firm's better performance in the CE is reflected in its higher stock market performance. Accordingly, our third hypothesis is as follows:

Hypothesis 3. (H3): Stock market performance is positively affected by firms' better performance in the CE.

Fig. 1 summarizes the conceptual framework underpinning our research hypotheses. The displayed economic/financial indicators are discussed in the next section.

3. Data and methodology

This section describes the sample-selection process, the definitions of the variable, and the empirical models.

3.1. Sample selection

To assess the impact of circular strategies on corporate financial performances, we rely on environmental and economic/financial data provided by Refinitiv DataStream. We select worldwide listed companies operating in the mining, manufacturing, utilities, and construction industries.[1] These industries are characterized by production patterns that heavily impact the environment (García-Sánchez et al., 2021). To observe how CE strategies have evolved for the same group of firms over a certain period, we select a sample for which data are available from 2010 to 2019. This choice makes descriptive analysis more informative and reduces data heterogeneity, making our econometric analysis more robust (Frees, 2004). We exclude data from the COVID-19 pandemic since corporate profitability and stock markets in the various regions of the world have been affected differently according to the lockdown policies, with potentially confounding effects on our analysis (Zhang et al., 2020; Scherf et al., 2022). The final sample consists of 1047 firms for a total of 10,470 observations over ten years. We grouped our sample firms into the following geographical areas: the EU, USA, Asia, and the rest of the world. Table 2 presents the sample distribution by industry and geographic area.

Of the sample firms, 40% are based in Asia, 30% in the USA, and 25% in the EU. Of the companies studied, 67% are manufacturers, while the rest are proportionally distributed across the other three sectors. The global panel enables us to grasp the pattern of evolving CE strategies over time and across geographical areas, as well as to seize the effect of more stringent regulations in different countries.

3.2. Measurement of CE strategies and CE score construction

Despite the academic and practical relevance of the concept, the literature has not yet reached a consensus on a clear-cut definition of CE (Kirchherr et al., 2017) and, consequently, on a standard metric to measure how deeply a company engages in circular practices. Zara et al. (2021a), for instance, propose a circularity score that includes a large set of indicators spanning from resource use and product responsibility to

[1] These sectors correspond to Sections B, C, D, E, and F of NACE Rev. 2.

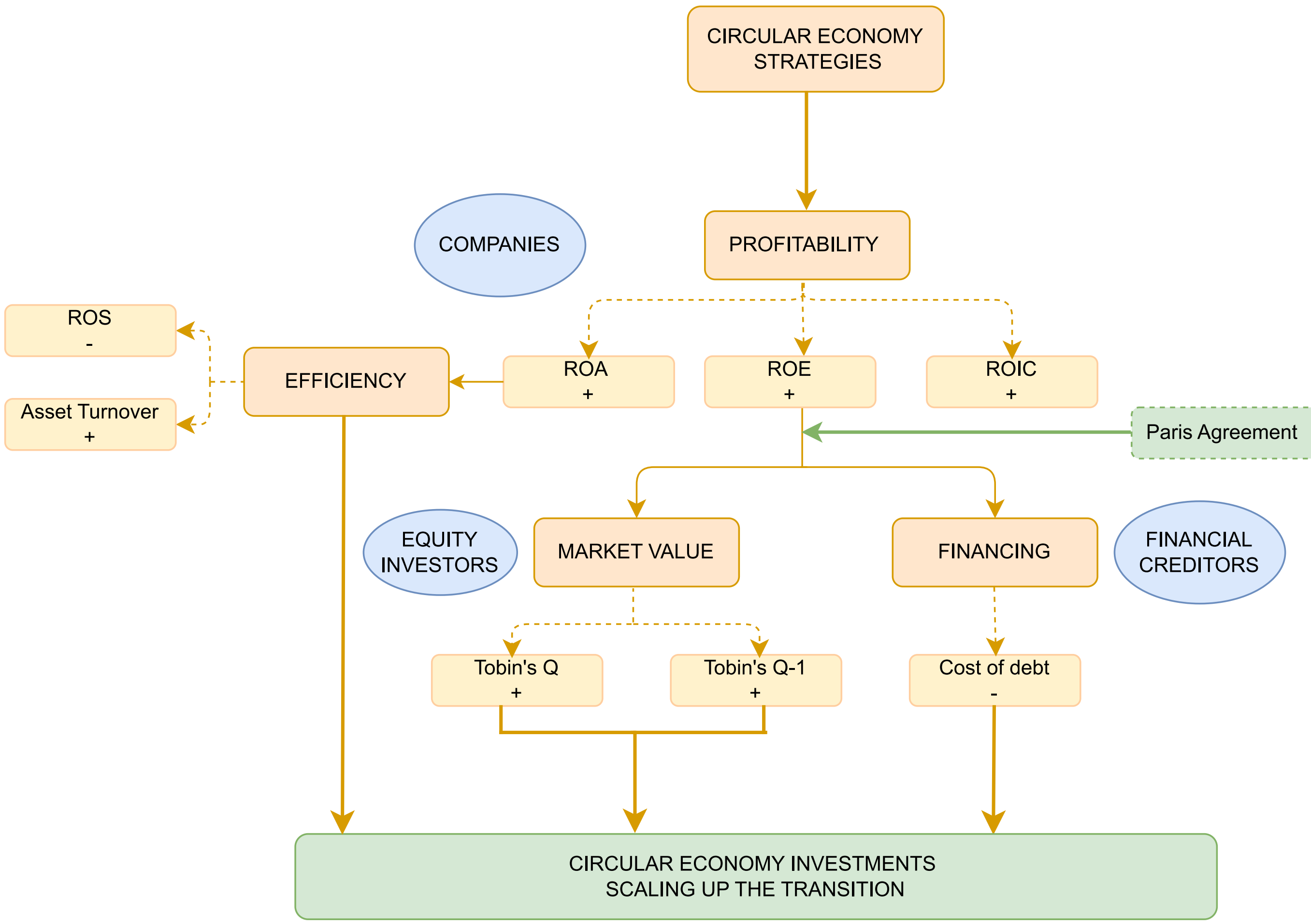

Fig. 1. Conceptual framework.

Table 2
Sample distribution by industry and region.

Industry Region	Mining N	Manufacturing N	Utilities N	Construction N	Total	Total (%)
Asia	16	241	25	44	326	31.13
Europe	17	155	25	29	226	21.58
USA	29	156	32	7	224	21.39
Rest of the World	67	154	29	21	271	25.88
Total	129	706	111	101	1047	100
Total (%)	12.32	67.43	10.60	9.64	100	

workforce and other corporate social responsible (CSR) strategies. García-Sánchez et al. (2021) develop a stricter CE index focused on 17 environmental practices to reduce the generation of waste and emissions and enhance the efficient use of materials and energy.

To capture the very essentials of the CE approach, we focus on a stringent definition of a circular economy proposed by Nobre and Tavares (2021), who view the CE as an economic system that targets zero waste and pollution through an efficient use and consumption of resources, materials that at their end-of-life return to either an industrial process or safely back to the environment, and the employment of renewable energy sources. By adopting this narrow definition, we focus on resource efficiency and closing loops strategies typical of the CE vision. In such a way, we prevent our CE measure from seizing the effect of business practices falling within the field of environmental sustainability but not strictly related to the CE approach.

To build a CE measure at the corporate level coherent with the above definition, we select the following eight environmental indicators from the Refinitiv DataStream database: *Waste reduction initiatives, E-waste reduction initiatives, Take-back and recycling initiatives, Eco-design products, Resources reduction/improvements, Renewable energy use, Policy water efficiency, and Policy energy efficiency*. These indicators, which are displayed in Table 3, refer to the following circular strategies: product eco-design and its end-of-life management through reverse logistics (Bocken et al., 2016; Geissdoerfer et al., 2020; Salvador et al., 2021), resource efficiency programs to narrow resource flows and material leakage (Bocken et al., 2016; Pieroni et al., 2020), recycling activities to “close the loop” and prevent loss of valuable materials (Bocken et al., 2016; Geissdoerfer et al., 2020), and internal policies to boost the shift to renewable energy (Korhonen et al., 2018; Rosa et al., 2019; Salvador et al., 2021, He et al., 2022) to ultimately limit dependence on finite resources. The indicators take a value of 1 if the company implements a certain CE initiative and 0 otherwise. Importantly, such indicators indicate whether a firm has adopted a certain CE strategy, which, in turn, may have an impact on revenue and cost structure, as well as an

Table 3
Indicator definitions.

Waste Reduction Initiatives
Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out any type of waste?
e-Waste Reduction Initiatives
Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out e-waste?
Take-back and Recycling Initiatives
Does the company reports about take-back procedures and recycling programs to reduce the potential risks of products entering the environment?
Eco-Design Products
Does the company report on specific products which are designed for reuse, recycling or the reduction of environmental impacts?
Resource Reduction \ Improvements
Does the company set specific objectives to be achieved on resource efficiency? \ Does the company comment on the results of previously set objectives?
Renewable Energy Use
Does the company make use of renewable energy?
Policy Water Efficiency
Does the company have a policy to improve its water efficiency?
Policy Energy Efficiency
Does the company have a policy to improve its energy efficiency?

influence on the financial markets' sentiment around the CE adoption. They do not measure, instead, the effectiveness of a circular strategy *per se*.

Based on these indicators, we build a CE score that captures the extent to which circular strategies are undertaken at a firm level. Therefore, we do not consider strategies based on the interaction between enterprises, such as industrial symbiosis and sharing systems. We then use a percentile rank scoring methodology (Rousseau, 2012), which we apply to the whole sample, consistent with investors comparing investment opportunities not only within single but also across regions. For each company and indicator, we assign a score defined by weighting the number of firms with a worse or the same value for the indicator at issue. We then compute the average of the eight scores and obtain a circular score for each company in the sample. The entire procedure is repeated for each year under analysis. The resulting CE score ranges from 0 to 1, where 0 corresponds to the lowest level of circularity and 1 to the highest.

3.3. Empirical strategy and variable definitions

We estimate different linear models to provide empirical evidence of the effect of corporate commitment to the CE on financial performances.

Our first model assesses the role of CE strategies in corporate profitability and operational efficiency (H1). The basic specifications of the model are as follows:

$$(Profitability/Operational\ Efficiency)_{i,t+1} = \alpha + \beta\ CE\ \mathrm{Score}_{i,t} + \gamma\ controls_{i,t} + \eta_i + \mu_t + \varepsilon_{it} \quad (1)$$

where i denotes the firm, and t the time period. *Profitability* alternatively assumes values of return on assets (ROA), return on invested capital (ROIC), and return on equity (ROE). These accounting-based measures are commonly included in credit rating systems (Rutkowska-Ziarko, 2020). *ROA* is calculated as net income divided by average total assets (Misani and Pogutz, 2015; Lucas and Noordewier, 2016) and indicates how effective a company is in deploying its assets to generate net income. *ROIC*, computed as net operating profit after taxes and dividends divided by the capital invested in the company (sum of equity and debt), indicates corporate efficiency in generating operating income given the amount of invested capital. Finally, *ROE* is computed by dividing net income by the average shareholder's equity (Misani and Pogutz, 2015; Gallego-Álvarez et al., 2015) and measures the firm's ability to generate earnings relative to its equity financing. We include in the model the following firm-specific factors that affect the financial indicators used as dependent variables (e.g., Delmas et al., 2015; Iwata and Okada, 2011): firm growth, size, capital intensity, and leverage. *Growth* is defined as the annual change in sales (Gallego-Álvarez et al., 2015) and is expected to positively impact corporate profitability. *Size* is measured as the natural logarithm of total assets (Blasi et al., 2021; Hussain et al., 2018; Misani and Pogutz, 2015), and *capital intensity* is proxied by the ratio of a firm's capital expenditure at time t to its total assets at time t-1 (Hussain et al., 2018). Evidence of the effect of these two variables on profitability performance is mixed (Song et al., 2017; Delmas et al., 2015; Fujii et al., 2013). Finally, *leverage* is computed as total liabilities divided by total assets (Zhou et al., 2022; Lucas and Noordewier, 2016; Delmas et al., 2015). The increasing use of debt for financing business is expected to have a negative effect on our dependent variables (Blasi et al., 2021). Since the effect of circular strategies on financial performance is not immediate, we lagged the *CE Score* and the control variables in line with prior research (e.g., Palea and Drogo, 2020). Region (η) and time (μ) fixed effects are also included in the model. Robust standard errors are clustered at the firm-level.

To delve into the relationship between circularity and profitability more deeply, we split ROA into its components, *ROS* and *Asset turnover*. The former is computed as the ratio of operating income to net sales, and measures corporate operational efficiency in turning sales into profits (Fujii et al., 2013; Iwata and Okada, 2011). The latter is obtained by dividing net sales by average total assets (Zhou et al., 2022; Fujii et al., 2013), and represents corporate efficiency in employing its assets to generate revenue.

To investigate the effect of CE strategies on the corporate cost of debt (H2), we estimate the following model:

$$COD_{i,t+1} = \alpha + \beta\ CE\ \mathrm{Score}_{i,t} + \gamma\ controls_{i,t} + \eta_i + \mu_t + \varepsilon_{it} \quad (2)$$

where *COD* is the cost of debt computed by dividing interest expenses by the average total debt (Palea and Drogo, 2020). In line with previous studies (Caragnano et al., 2020; Palea and Drogo, 2020; Eliwa et al., 2021), model 2 includes the following set of control variables: *Size, ROA, working capital*, and *leverage*. *Size*, *ROA*, and *leverage* are defined as in previous models, while *working capital* is computed as working capital divided by total assets and captures the level of liquidity of the company.

Finally, we investigate the impact of circular business strategies on market value by utilizing the following model:

$$Market\ value_{i,t} = \alpha + \beta\ CE\ \mathrm{Score}_{i,t} + \gamma\ controls_{i,t} + \eta_i + \mu_t + \varepsilon_{it} \quad (3)$$

We adopt two different measures of *market value* as dependent variables. We use both Tobin's Q, which describes the present value of a firm's expected future net cash flows (Zhou et al., 2022; Hassan and Romilly, 2018; Nishitani and Kokubu, 2012), and Tobin s' Q - 1, which captures the role of intangible assets (such as patents, brand names, trademarks, and firm goodwill) as factors of value creation (Konar and Cohen, 2001; Iwata and Okada, 2011; Palea and Santhià, 2022). Tobin's Q is computed as the sum of market capitalization and book value of total liabilities divided by the book value of total assets (Misani and Pogutz, 2015; Palea and Santhià, 2022). Under the hypothesis of an efficient stock market (Fama, 1970), no variable is lagged in the regression. In line with other studies, we use its logarithm for the sake of normality (Iwata and Okada, 2011). Following Konar and Cohen (2001), the value of intangible assets is estimated by subtracting 1 from the value of Tobin's Q.[2]

[2] As suggested by Konar and Cohen (2001), the MV of the firm can be expressed as the sum of the value of its tangible assets (VT) and its intangible assets (VI). Since Tobin's Q is defined as the ratio MV/VT, which can be rewritten as 1 + VI/VT, Tobin's Q – 1 corresponds to VI/VT and may be interpreted as the value of the intangible assets of the firm.

4. Results and discussion

This section presents and discusses the summary statistics, correlation matrix, and results of the regression models described in the previous section.

4.1. Descriptive statistics and correlation

Table 4 reports the sample distribution for each indicator included in our CE score from 2010 to 2019.

As Table 4 displays, the adoption of CE strategies as captured by each indicator shows an increasing trend. *Policy water efficiency* exhibits the highest growth rate, followed by R*enewable energy use* and *Waste reduction initiatives*. On the contrary, *Take-back and recycling initiatives* and *Eco-design products* increased less and still have a low implementation rate at the end of the period (around 18% and 25%, respectively). During the decade 2010–2019, firms from Asia and the rest of the world experienced the sharpest increase throughout the whole set of indicators, while companies based in the EU or USA have witnessed a more modest increase. According to the most recent data, the efficient use of energy and materials and the employment of renewables are more advanced in the EU than in other regions. In contrast, Asian countries have concentrated on developing the eco-design of products.

Table 5 reports the descriptive statistics for the quantitative variables employed in the econometric models.

Our main independent variable*, CE score*, shows similar mean and median values, equal to 50% and 52.44%, respectively. A total of 75% of the observations have a score value equal to or less than 59.55%. Given a minimum value of 21.59% and 25% observations with a score value equal to or less than 40.82%, most companies have a score value close to the average value. Little heterogeneity in the index is in line with other measures of circularity (Zara et al., 2021b). The values of financial indicators are also coherent with previous studies (Misani and Pogutz, 2015; Delmas et al., 2015).

Table 6 presents a correlation matrix for our regression variables.

As expected, the *CE score* has a positive and significant correlation with *ROA, ROE, ROIC,* and *Asset turnover*. The correlation with *Asset turnover* presents the highest absolute coefficient, suggesting that CE strategies exert their most significant impact on capital efficiency. The correlation between *CE score* and *ROS*, instead, is significantly negative,

Table 4
CE indicators distribution by region and year.

Year Variable	2010	2011	2012	2013	2014	2015	2015	2017	2018	2019
Waste Reduction Initiatives (Y, %)										
EU	79.20	79.65	82.30	81.42	80.97	82.30	84.07	85.84	90.27	93.81
USA	61.61	64.73	66.07	64.73	65.63	68.75	75.45	75.45	81.25	87.05
Asia	64.11	65.34	69.02	68.71	70.25	72.39	79.45	86.20	90.80	95.09
Rest of the World	57.56	60.15	64.21	64.94	64.94	68.63	72.32	76.38	79.70	83.76
Per Year (%)	65.14	66.95	70.02	69.62	70.2	72.79	77.75	81.28	85.76	90.16
e-Waste Reduction Initiatives (Y, %)										
EU	9.73	12.39	14.16	12.39	11.95	12.83	12.83	13.72	13.72	16.37
USA	9.73	12.39	14.16	12.39	11.95	12.83	12.83	13.72	13.72	16.37
Asia	9.20	9.20	11.96	11.04	11.96	10.74	12.88	15.34	17.48	21.17
Rest of the World	11.07	12.55	15.13	15.13	14.02	12.55	12.92	14.76	15.87	16.97
Per Year (%)	11.56	13.66	15.28	14.23	13.46	12.99	14.42	15.57	16.81	19.67
Take-back and Recycling Initiatives (Y, %)										
EU	17.70	18.58	19.47	19.47	18.58	18.14	19.47	19.03	19.91	20.35
USA	18.30	20.09	18.30	16.96	15.18	16.07	16.52	17.86	18.30	20.54
Asia	17.48	20.86	21.78	19.94	18.71	16.87	18.40	18.71	19.33	21.47
Rest of the World	9.23	9.23	9.96	9.96	9.59	9.23	9.23	8.86	9.96	9.96
Per Year (%)	15.57	17.19	17.48	16.62	15.57	15	15.85	16.05	16.82	18.05
Eco-Design Products (Y, %)										
EU	25.22	23.89	22.57	20.80	19.91	20.35	20.80	19.47	20.35	27.88
USA	16.96	14.73	14.73	15.18	14.29	16.07	16.52	15.63	17.86	25.00
Asia	25.15	24.23	26.38	25.77	26.07	24.54	25.77	26.69	26.99	28.53
Rest of the World	12.18	10.70	10.33	9.59	12.18	14.02	15.50	15.87	17.34	21.03
Per Year (%)	20.05	18.63	18.9	18.24	18.63	19.1	20.05	19.96	21.1	25.69
Resource Reduction\Improvements (Y, %)										
EU	50.00	51.33	55.31	53.98	53.54	58.85	57.52	59.73	61.50	64.60
USA	38.84	41.96	41.07	40.18	38.39	43.30	41.96	44.64	49.11	55.36
Asia	35.58	38.04	42.02	40.80	41.10	40.49	39.26	43.25	50.00	57.36
Rest of the World	28.04	29.52	33.95	33.21	31.37	36.90	36.53	42.44	47.60	53.14
Per Year (%)	37.44	39.54	42.61	41.55	40.69	44.12	43.09	46.89	51.68	57.39
Renewable Energy Use (Y, %)										
EU	55.75	58.85	63.27	65.04	68.14	68.14	71.24	76.11	78.32	83.63
USA	39.73	44.64	45.54	44.64	46.43	46.43	48.66	50.89	55.80	63.84
Asia	42.94	47.55	52.15	52.76	52.45	54.60	57.36	62.58	67.79	70.55
Rest of the World	32.10	37.27	45.76	45.76	45.76	47.23	49.45	53.14	57.56	61.99
Per Year (%)	42.21	46.7	51.48	51.86	52.81	53.87	56.45	60.55	64.86	69.73
Policy Water Efficiency (Y, %)										
EU	63.27	66.81	68.58	68.58	68.14	73.01	73.45	76.11	79.20	84.96
USA	50.89	53.57	57.14	58.04	59.82	64.73	67.86	70.09	75.45	84.82
Asia	36.20	40.80	46.32	47.55	51.23	55.83	65.03	70.25	74.85	80.67
Rest of the World	50.92	53.51	57.56	58.30	64.94	69.74	71.96	75.65	80.07	83.76
Per Year (%)	49.00	52.43	56.35	57.11	60.27	65.04	69.24	72.88	77.27	83.29
Policy Energy Efficiency (Y, %)										
EU	80.09	81.42	85.84	86.28	87.17	91.15	91.15	93.81	94.25	96.02
USA	62.05	65.18	68.30	66.96	67.41	68.30	71.43	74.11	78.13	83.48
Asia	69.02	72.70	75.46	75.77	77.30	79.14	86.20	90.18	93.25	94.79
Rest of the World	57.56	60.15	65.68	66.05	70.48	73.80	76.75	80.07	84.13	86.72
Per Year (%)	66.96	69.72	73.64	73.64	75.55	78.03	81.67	84.91	87.87	90.55

Table 5
Summary statistics: financial variables and CE Score.

Variable	Mean	SD	Min	Pctl. 25	Median	Pctl. 75	Max
ROA	4.91	6.3	−16.02	1.96	4.32	7.66	26.13
ROE	11.74	19.08	−60.81	5.02	10.51	17.46	101.42
ROIC	8.17	9.16	−21.64	3.81	7.13	11.95	43.16
ROS	12.29	11.08	−16.36	5.33	10.11	17.53	49.12
Asset turnover	0.79	0.46	0.1	0.44	0.74	1.02	2.5
Tobin's Q	1.57	1.02	0.59	1.00	1.25	1.77	6.99
COD	0.04	0.03	0.00	0.02	0.04	0.06	0.21
Growth	6.32	17.93	−40.96	−2.26	4.48	12.73	83.3
Size	17.6	2.45	12.92	15.68	17.33	19.52	23.97
Capital intensity	0.05	0.05	0.00	0.02	0.04	0.07	0.27
Leverage	0.26	0.15	0.00	0.16	0.25	0.35	0.67
Working capital	0.44	0.18	0.01	0.31	0.43	0.56	0.84
CE Score	50.02	12.89	21.59	40.82	52.44	59.55	80.75

The financial variables are winsorized at 1 and 99 percentiles.

Table 6
Correlation matrix: financial variables and CE Score.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) ROA	1.00												
(2) ROE	0.74	1.00											
	(0.000)												
(3) ROIC	0.94	0.76	1.00										
	(0.000)	(0.000)											
(4) ROS	0.53	0.38	0.47	1.00									
	(0.000)	(0.000)	(0.000)										
(5) Asset turnover	0.24	0.22	0.28	−0.33	1.00								
	(0.000)	(0.000)	(0.000)	(0.000)									
(6) Tobins' Q	0.61	0.47	0.61	0.33	0.25	1.00							
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)								
(7) COD	0.03	0.03	0.10	0.11	0.00	0.12	1.00						
	(0.002)	(0.002)	(0.000)	(0.000)	(0.668)	(0.000)							
(8) Growth	0.23	0.16	0.21	0.22	0.05	0.10	0.10	1.00					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(9) Size	−0.05	−0.06	−0.10	−0.04	−0.06	−0.22	−0.34	−0.03	1.00				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)					
(10) Capital intensity	0.07	0.02	0.04	0.19	−0.07	0.04	0.06	0.19	0.00	1.00			
	(0.000)	(0.068)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.911)				
(11) Leverage	−0.27	−0.05	−0.23	0.02	−0.24	−0.13	−0.08	−0.03	0.00	0.04	1.00		
	(0.000)	(0.000)	(0.000)	(0.123)	(0.000)	(0.000)	(0.000)	(0.001)	(0.659)	(0.000)			
(12) Working capital	0.25	−0.05	0.11	0.12	−0.07	0.09	0.02	0.05	−0.02	0.09	−0.70	1.00	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.071)	(0.000)	(0.110)	(0.000)	(0.000)		
(13) CE Score	0.05	0.08	0.07	−0.04	0.13	0.05	−0.09	−0.08	0.26	−0.08	−0.02	−0.14	1.00
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.084)	(0.000)	

The financial variables are winsorized at 1 and 99 percentiles.

pointing to CE strategies decreasing operating margins, at least in the short term. Finally, the correlation between the *CE score* and the cost of debt is negative, in line with expectations, and statistically significant.

4.2. Multivariate analysis

Tables 7–9 display the results of our regressions. Table 7 displays the results for the regression with *ROA*, *ROIC*, and *ROE* as accounting-based indicators.

The positive and significant coefficient of the *CE score* (coefficient = 0.0448, 0.0747, and 0.1523, respectively; p-value < 0.01) indicates that including circularity as part of the broader business strategy has a positive impact on corporate profitability. Among the control variables, *Growth* shows significant and positive coefficients in all three models (p-value < 0.01) and *Leverage* significant and negative coefficients (Iwata and Okada, 2011). *Size* has a significant and negative coefficient with *ROIC* (p-value < 0.05), while C*apital intensity* has a negative coefficient with *ROA* and ROIC. The adjusted R^2 is relatively low, ranging from 0.0483 to 0.0929, which is in line with previous studies on CE innovations (Blasi et al., 2021; Majid et al., 2020).

Table 8 displays the results of the regression with *ROS* and *Asset turnover* as dependent variables.

Overall, our findings show that circular business strategies exert a positive impact on corporate profitability. The results indicate that *CE score* exhibits a positive and significant relationship only with *Asset turnover* (coefficient = 0.0055, p-value < 0.01), suggesting that a circular approach increases the efficiency of a company using its assets to generate revenues. In line with Antonioli et al. (2022), CE strategies do not exert, instead, a significant effect on *ROS* (coefficient = −0.0133, p-value > 0.1). This result could be due to an increase in research and development costs or higher amortization related to new and more efficient equipment that, at least in the short term, may counterbalance cost savings related to other CE strategies. Among the control variables, *Growth* has a positive and significant effect on all dependent variables; *Size* and *Capital intensity* have a negative and significant effect on *Asset turnover,* and *Capital intensity* has a positive and significant effect on *ROS*. *Leverage* has a significant and negative effect only on *Asset turnover* (p-value < 0.01).

Table 9 reports the results for the regression with *COD*, *ln(Tobins'Q)*, and *Tobins'Q - 1* as dependent variables.

Findings indicate no significant relationship between *CE score* and *COD* (coefficient = −0.0069, p-value > 0.1), suggesting that creditors do not consider virtuous CE strategies in credit pricing. This result is consistent with prior research in other fields of environmental

Table 7
Regression (1) results: CE Score and profitability.

	ROA (t+1) (1)	ROIC (t+1) (2)	ROE (t+1) (3)
CE Score	0.0448***	0.0747***	0.1523***
	(0.0113)	(0.0157)	(0.0328)
Growth	0.0554***	0.0708***	0.1678***
	(0.0053)	(0.0075)	(0.0159)
Size	−0.1288	−0.2841**	−0.2632
	(0.0945)	(0.1308)	(0.2661)
Capital intensity	−5.1568*	−11.6251***	−0.2426
	(2.9822)	(4.0109)	(8.2195)
Leverage	−9.3881***	−10.7515***	−7.2284**
	(1.0197)	(1.5174)	(3.4249)
Constant	7.6666***	13.6088***	11.2570***
	(1.4620)	(2.0482)	(4.0055)
Year effect	YES	YES	YES
Region effect	YES	YES	YES
Observations	10,470	10,470	10,470
Adjusted R^2	0.0929	0.0839	0.0483
F Statistic	64.0686***	57.4201***	32.2715***

Robust standard errors clustered by firm are in parentheses. ***, **, * represent significance levels at $p < 0.01$, $p < 0.05$ and.
$p < 0.10$, respectively. The financial variables are winsorized at 1 and 99 percentiles.

Table 8
Regression (1) results: CE Score and operational efficiency.

	ROS (t+1) (1)	Asset Turnover (t+1) (2)
CE Score	−0.0133	0.0055***
	(0.0217)	(0.0010)
Growth	0.1166***	0.0009***
	(0.0100)	(0.0003)
Size	0.2913	−0.0249***
	(0.1916)	(0.0079)
Capital intensity	17.1585**	−0.8052***
	(6.9195)	(0.2209)
Leverage	1.1980	−0.6815***
	(2.0972)	(0.0754)
Constant	7.3654***	1.1784***
	(2.8040)	(0.1207)
Year effect	YES	YES
Region effect	YES	YES
Observations	10,470	10,470
Adjusted R^2	0.0626	0.0981
F Statistic	42.1477***	67.9732***

Robust standard errors clustered by firm are in parentheses. ***, **, * represent significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.10$, respectively. The financial variables are winsorized at 1 and 99 percentiles.

sustainability (e.g., Campiglio et al., 2019). The coefficient of the *CE score*, instead, is always positive and significant in the regressions with *ln (Tobins'Q)* and *Tobins'Q - 1* as dependent variables (coefficient = 0.0063 and 0.0099, respectively, p-value < 0.01), indicating that the stock market perceives CE strategies as growth opportunities. These findings are consistent with prior research (e.g., Palea and Santhià, 2022; Iwata and Okada, 2011). When interpreting them together with those for *ROS*, they also suggest that CE strategies may negatively affect costs in the short-term while being positively incorporated into investors' long-term profitability expectations (Delmas et al., 2015; Zhou et al., 2022; Hassan and Romilly, 2018; Nishitani and Kokubu, 2012). All the control variables have significant coefficients for both *ln(Tobins'Q)* and *Tobins'Q - 1*.

4.3. Further analyses

Table 8 reveals that corporate efficiency in using assets takes advantage of CE practices. Against this background, this section further analyzes the circular-related strategies that play a major role in increasing asset efficiency. To this end, we perform a regression analysis

Table 9
Regression (2) (3) results: CE Score, cost of Debt and Market Value.

	COD (t+1) (1)	Ln(Tobin's Q) (t) (2)	Tobin's Q-1 (t) (3)
CE Score	−0.0069	0.0063***	0.0099***
	(0.0058)	(0.0009)	(0.0021)
Size	−0.2858***	−0.0570***	−0.0914***
	(0.0492)	(0.0058)	(0.0194)
Leverage	0.1809***	−0.3361***	−1.0144***
	(0.0514)	(0.0888)	(0.2143)
ROA	−0.0088		
	(0.0136)		
Working capital	1.3600*		
	(0.7315)		
Growth		0.0030***	0.0057***
		(0.0003)	(0.0007)
Capital intensity		0.5573**	0.9899**
		(0.2171)	(0.4785)
Constant	9.1826***	1.0888***	1.7671***
	(0.8240)	(0.1040)	(0.2932)
Year effect	YES	YES	YES
Region effect	YES	YES	YES
Observations	10,470	10,470	10,470
Adjusted R^2	0.1527	0.1214	0.1090
F Statistic	111.9730***	104.3037***	76.3409***

Robust standard errors clustered by firm are in parentheses. ***, **, * represent significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.10$, respectively. The financial variables are winsorized at 1 and 99 percentiles.

between *Asset turnover*, as a dependent variable, and the following indicators, representing the key operational strategies for implementing a CE at the company level: *Waste reduction initiatives, Resources reduction/improvements, Take-back and recycling initiatives, Eco-design products.* The specification of the model is as follows:

$$Asset\ Turnover_{i,t+1} = \alpha + \beta \sum CE\ indicators_{i,t} + \gamma\ controls_{i,t} + \eta_i + \mu_t + \varepsilon_{it} \quad (4)$$

where *CE indicators* are those listed above, and all other variables are defined as in regression (1).

Table 10 reports the regression results and indicates that all the four

Table 10
Regression (4) results: Indicators and Asset Turnover.

	Asset Turnover (t+1)
Waste reduction initiatives	0.0547**
	(0.0265)
Resources reduction/improvements	0.0580***
	(0.0206)
Take-back and recycling initiatives	0.0670**
	(0.0267)
Eco-Design products	0.1420***
	(0.0287)
Growth	0.0009***
	(0.0003)
Size	−0.0256***
	(0.0078)
Capital intensity	−0.6933***
	(0.2184)
Leverage	−0.6584***
	(0.0752)
Constant	1.3623***
	(0.1216)
Year effect	YES
Region effect	YES
Observations	10,470
Adjusted R^2	0.1129
F Statistic	67.6097***

Robust standard errors clustered by firm are in parentheses. ***, **, * represent significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.10$,respectively.
The financial variables are winsorized at 1 and 99 percentiles.

indicators have significant and positive coefficients.

According to our overall findings, both product and process innovations related to a CE can positively affect capital efficiency. *Eco-Design design products* has the largest coefficient (coefficient = 0.1420, p-value <0.01), thus suggesting that the most effective contribution to capital efficiency comes from this strategy. Consistent with previous studies (Antonioli et al., 2022; Demirel and Danisman, 2019), this result provides empirical support for integrating CE considerations early in the product design process. *Take-back and recycling initiatives* (coefficient = 0.0670, p-value < 0.05) exert a less pronounced, but still positive effect, on *Asset turnover*. Reverse logistics, therefore, play a role in increasing capital efficiency. *Waste reduction initiatives* (coefficient = 0.0547, p-value < 0.05) and *Resources reduction/improvements* (coefficient = 0.0580, p-value < 0.01) also affect *Asset turnover* positively, although more weakly, indicating that a reduction in waste processing and resource demand also contributes to extracting greater value from assets.

We then focus on the cost of debt, for which we find little evidence of a beneficial effect of CE strategies. We wonder whether international engagement in addressing climate change may have changed creditors' attitudes toward CE strategies. In effect, prior research shows that the 2015 Paris Agreement is a turning point around which investors have become aware of policymakers' strong commitment to fighting climate change (Monasterolo and de Angelis, 2020; Palea and Drogo, 2020). The year 2015 also marked a fundamental step in the circularity transition journey in the European Union since the European Commission adopted its first Circular Economic Action Plan. Against this background, we deepen our analysis by investigating whether capital providers—both creditors and stock market participants—have started to look differently at the CE approach since 2015. To this end, we run the same regression models 2 and 3, to which we add the dummy variable *post 2015* and its interaction with the CE score as follows:

$$COD_{i,t+1} \Big/ Market\ value_{i,t} = \alpha + \beta\ CE\ Score_{i,t} + \delta\ Post\ 2015 + \lambda\ CE\ Score_{i,t} * Post\ 2015 + \gamma\ controls_{i,t} + \eta_i + \mu_t + \varepsilon_{it} \quad (5)$$

Table 11 shows the regression results.

The signs and meaning of the *CE score* persist. The *Post 2015* coefficient is negative and significant for *ln(Tobins'Q)* and *Tobins'Q - 1* (coefficient = - 0.2360 and - 0.4021 respectively, p-value < 0.01). According to these results, after 2015 the financial market started to perceive the most polluting sectors, such as those covered by our sample, as riskier. The interaction term for both *ln(Tobins'Q)* and *Tobins'Q - 1* is positive and significant (coefficient = 0.0043 and 0.0091, respectively; p-value < 0.01), suggesting that the stock market increasingly penalizes firms with worse CE performance.

While the *Post 2015* coefficient is not significant for *COD* (coefficient = 0.0001, p-value > 0.1), the interaction term is negative and significant (coefficient = −0.0217, p-value < 0.01), indicating increasing penalization for firms with worse CE after 2015. These results are consistent with prior research (e.g., Palea and Drogo, 2020) showing that, since 2015, creditors have become increasingly aware of policymakers' strong commitment to decarbonize the economy. Taken as a whole, our results suggest that public policies can be effective in leading the financial system to penalize environmentally worst-performing firms.

Table 12 reports our overall results summary.

Table 11

Regression (4) results: Circularity, Market Value and Cost of Debt pre and post Paris Agreement.

	COD (t+1) (1)	Ln(Tobin's Q) (t) (2)	Tobin's Q-1 (t) (3)
CE Score	0.0001	0.0044***	0.0069***
	(0.0063)	(0.0009)	(0.0020)
Post 2015	0.2195	−0.2360***	−0.4021***
	(0.3343)	(0.0478)	(0.1072)
Size	−0.2840***	−0.0425***	−0.0922***
	(0.0491)	(0.0084)	(0.0195)
Leverage	0.1784***	−0.4396***	−1.0047***
	(0.0513)	(0.0857)	(0.2142)
Growth		0.0031***	0.0057***
		(0.0003)	(0.0007)
Capital intensity		0.5446**	0.9620**
		(0.2239)	(0.4788)
ROA	−0.0074		
	(0.0136)		
Working capital	1.3300*		
	(0.7297)		
CE Score x Post 2015	−0.0217***	0.0043***	0.0091***
	(0.0062)	(0.0009)	(0.0021)
Constant	8.8080***	0.9209***	1.9302***
	(0.8296)	(0.1287)	(0.3048)
Year effect	YES	YES	YES
Region effect	YES	YES	YES
Observations	10,470	10,470	10,470
Adjusted R^2	0.1545	0.1603	0.1119
F Statistic	107.2706***	112.0397***	74.2580***

Robust standard errors clustered by firm are in parentheses. ***, **, * represent significance levels at p < 0.01, p < 0.05 and p < 0.10,respectively.
The financial variables are winsorized at 1 and 99 percentiles.

5. Conclusions

The CE approach is considered a key strategy for pursuing sustainable development. Nonetheless, empirical research has widely disregarded the impact of the circular transition on corporate financial performance, focusing instead on its environmental effects. This study fills this gap by investigating the effect of CE strategies on financial indicators in a sample of listed companies from different regions of the world over the 2010–2019 period. Our longitudinal analysis makes it possible to observe the behavior of the same group of firms over time and across regions.

By constructing a CE score based on a rigorous definition of a CE, we perform a multivariate analysis to identify the consequences of undertaking a circular transformation on corporate profitability, operational efficiency, market valuation, and debt financing.

Our study contributes to the academic knowledge of CE uptake at firm level and advances the extant literature on several aspects. We demonstrate that adopting CE strategies can bring multiple benefits, both in terms of economic return and efficiency, and in terms of ease of raising capital. First of all, our econometric estimations indicate that CE initiatives contribute to better financial performances in terms of profitability and market value. Firms that are more proactive and minimize their exposure to climate-related risks through CE practices seize new opportunities for profitability. Therefore, our results encourage managers to undertake initiatives within the CE domain to improve their economic performance. Moreover, econometric estimations suggest that capital providers look at the CE as a promising or less risky strategy. However, differently from stock market participants, creditors started penalizing firms with worse CE performance only after the Paris Agreement (and, arguably, the Circular Economy Action Plan in the EU). Taken as a whole, findings suggest that the year 2015 represented a turning point for the financial markets, which started incorporating the

Table 12
Results summary.

		CE Strategies		Waste reduction initiatives		Resources reduction/improvements		Take-back and recycling initiatives		Eco-Design products		CE Strategies Post Paris	
		ExpectedEffect	Verified	Expected Effect	Verified	Expected Effect	Verified	Expected Effect	Verified	Expected Effect	Verified	Expected Effect	Verified
Profitability	ROA	+	✓										
	ROIC	+	✓										
	ROE	+	✓										
Efficiency	ROS	−											
	Asset Turnover	+	✓	+	✓	+	✓	+	✓	+	✓		
Debt Financing	Cost of debt	−										−	✓
Equity	ln(Tobin's Q)	+	✓									+	✓
Market Value	Tobin's Q-1	+	✓									+	✓

expectation of more stringent requirements on emissions into their decision making. Finally, our results provide helpful information for policymakers by showing that the CE is a tool not only for addressing environmental issues but also for economic growth purposes. Designing policies to shape market demand and scale up the impact of the CE can therefore be beneficial for both the environment and the economy.

By disaggregating the different typologies of CE-related activities, our analysis indicates that all circular strategies included in our score play a role in increasing capital efficiency, with eco-design, take-back, recycling systems, and waste reduction in decreasing order of relevance. Our findings therefore show that a comprehensive approach to policy making is needed, which includes interventions at every stage of a product's life cycle, from design to resource recovery.

Our study also paves the way to further analyses of the economic effects of CE strategies, and can be replicated for other industries. For instance, agriculture is one of the highest emitting and most affected sectors by climate change (FAO, 2020). Climatic conditions, for instance, are one of the key determinants of plant growth (Fahad et al., 2021b). Improving food security and safety is also key for achieving a "zero hunger" target according to the United Nations' sustainable development objective 2 (Fahad et al., 2021a). The CE has been proved to be a promising strategy for supporting sustainable, restorative, and regenerative agriculture (Velasco-Muñoz et al., 2021). Replicating our methodology within agriculture would well complement the research performed by agricultural and food scientists with an economic assessment of sector-specific CE practices.

Our analysis, however, suffers from some limitations. The most important is related to the Refinitiv DataStream indicators, which are not exhaustive of peculiar features related to a CE, such as the intensity of usage of products and assets and the product-service system. Also, they do not focus on the successful achievements of the CE, but rather on the strategic approach behind its implementation. Finally, the binary scale of indicators does not capture the extent to which companies adopt individual CE strategies but only whether they do so. However, Refinitiv DataStream is the only source of economic-environmental data at enterprise level that makes it possible to work on such a broad global panel and grasp the pattern of evolving CE strategies over time and geographical areas. As more detailed data around a CE become available, research will be able to improve the accuracy of CE measurements. Further study could also benefit from more granular analyses at a single-country and specific sector level to account for context-specific factors capable of explaining the adoption of CE practices and their effects on financial performances.

Credit author statement

Vera Palea: Conceptualization, Methodology, Writing, Supervision; Cristina Santhià;: Methodology, Data curation, Formal analysis, Writing Aline Miazza: Methodology, Data curation, Formal analysis, Writing

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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