Journal of Environmental Management 349 (2024) 119544

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Scaling up the transition: The role of corporate governance mechanisms in promoting circular economy strategies

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ARTICLE INFO

Handling Editor: Prof Raf Dewil

JEL classification:
M14
M48
O1
Q01
Q5

Keywords:
Circular economy
Corporate governance
Circular strategies
Sustainability
ESG

ABSTRACT

This study examines the role of corporate governance (CG) mechanisms in promoting Circular Economy (CE) strategies among non-financial listed companies in manufacturing industries, which is still a relatively unexplored topic in the CE literature. Our findings indicate that the presence of stakeholder engagement practices, sustainability reporting, and environment management teams have a direct impact on the adoption of CE strategies, while the presence of a CSR committee, adherence to the United Nations' Global Compact, and executives' compensation linked to environmental, social, and corporate governance performance do not have a direct effect but support CE strategies through other mechanisms. Overall, this study provides valuable insights for policymakers and managers as it shows that CG mechanisms can be used to promote the adoption of CE business models, thus contributing to climate risk mitigation objectives.

1. Introduction

In recent years, the concept of circular economy has gained significant attention among policymakers worldwide (e.g., European Commission [EC], 2020a; United States Environmental Protection Agency, 2022). Transitioning to a circular economy (hereafter CE) is considered key to achieving the Paris Agreement targets (United Nations, 2021). Remarkably, effective implementation of CE policies could reduce CO_2 emissions by up to 55.3% by 2050 (Aguilar-Hernandez et al., 2021) and generate economic benefits of $4.5 trillion by 2030 (World Economic Forum, 2019). Unlike the prevailing linear "take-make-use-dispose" model of mass production and consumption (Esposito et al., 2018), a CE can decouple economic growth from environmental degradation (Ellen MacArthur Foundation, 2013; EC, 2015). By prioritizing resource efficiency and waste reduction, a CE establishes self-sustaining closed loops in the production system, where resources are reused, recycled or repurposed until they become exhausted (e.g., Genovese et al., 2017).

The manufacturing industry plays an important role in reorienting the economic system according to the CE paradigm (Pieroni et al., 2021). For this reason, academic research has started investigating which drivers can lead businesses to adopt a CE model, such as pressures from public policy (e.g., Cainelli et al., 2020; Siedschlag et al., 2022), market demands and orientation (e.g., Cainelli et al., 2020; Schmidt et al., 2021), economic incentives and environmental commitment (e.g., Centobelli et al., 2021; Gusmerotti et al., 2019), financial resources (e.g., Kiefer et al., 2019; Triguero et al., 2022), and ethical leadership (Cheffi et al., 2023). Instead, corporate governance (hereafter CG) mechanisms have not received much attention in this regard. Therefore, understanding which CG mechanisms enhance firms' attitude to developing and implementing CE strategies can be relevant to managers and policymakers for scaling up the transition to more sustainable businesses.

Our study bridges this gap in the literature by using an international sample of non-financial listed companies operating in manufacturing industries, during the period 2010–2021. We build on a shared definition of the circular economy that encompasses both resource reduction and reuse (Nobre and Tavares, 2021; Palea et al., 2023) and focus on CG mechanisms expressing a sustainability orientation (Birindelli and Palea, 2022). We test whether firms are more likely to adopt CE strategies in the presence of different CG mechanisms. These include the presence of a board-level corporate social responsibility committee

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https://doi.org/10.1016/j.jenvman.2023.119544
Received 25 July 2023; Received in revised form 19 October 2023; Accepted 4 November 2023

(hereafter *CSR committee*), the use of executives' compensation linked to environmental, social, and governance performance (hereafter *ESG executive compensation*), the adherence to the United Nations' Global Compact (hereafter *UNGC signatory*), the establishment of an *environment management team*, the implementation of *stakeholder engagement* actions, and the adoption of *sustainability reporting*.

Our analysis shows that *stakeholder engagement*, *environment management teams*, and *sustainability reporting* positively affect firms' likelihood of adopting CE strategies. In contrast, *CSR Committee*, *UNGC signatory*, and *ESG executive compensation* do not have a significant direct impact. However, additional analyses suggest that these latter mechanisms promote *stakeholder engagement*, *sustainability reporting*, and *environment management teams*, hence playing an indirect role in the adoption of circular practices.

Our findings contribute to the extant literature and yield important implications for practitioners, investors, and policymakers. First of all, our analysis well complements Birindelli and Palea (2022), who focused on the banking sector, highlighting that CG mechanisms foster CE strategies in the manufacturing industries. Our results also extend Palea et al. (2023), who examined how the adoption of CE strategies improves firms' economic performance and stock prices by indicating which specific CG mechanisms support those CE strategies. In this respect, our findings provide informed input for policymaking in the field of corporate governance. Moreover, this study can also be of interest to investors, who should consider CE strategies in shaping forward-looking, rather than point-in-time, asset allocation strategies focusing on sustainable activities, as highlighted by the literature on sustainable finance (Moneva et al., 2023; Sepetis, 2022). Finally, this study shows that political commitment to environmental objectives has significantly impacted the diffusion of some CG mechanisms and CE practices over time and across regions.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature and presents our conceptual framework. Section 3 describes the research design and data. Section 4 presents the descriptive analysis, while Section 5 reports the results of the econometric analyses. Section 6 concludes and provides the main implications of our study.

2. Literature review

A circular economy is a production system targeting zero waste and pollution in extraction, use, and final consumption (Nobre and Tavares, 2021) to decouple economic growth from environmental degradation (Ellen MacArthur Foundation, 2013; EC, 2015). Unlike the traditional "take-make-use-dispose" production paradigm, it aims to efficiently use and consume resources, employing clean and renewable energy sources and "circular" closed loops of materials. Our study investigates which corporate governance mechanisms drive the adoption of such a production paradigm in manufacturing listed companies.

The academic literature on what drives strategies to improve the environmental, social, or governance outcomes of business activities dates back at least to the 1980s (e.g., Cowen et al., 1987; Freeman, 1984). To date, researchers have employed a variety of theoretical approaches to explain corporate sustainability engagement, including institutional, legitimacy, stakeholder, and resource-focused theories (e.g., Aguinis and Glavas, 2012; Searcy, 2012; Zhang et al., 2019). From an institutional perspective, organizations facing external pressures adopt the prevailing models of strategies through coercive, mimetic, or normative processes (Dimaggio and Powell, 1983; Meyer and Rowan, 1977). From a stakeholder theory perspective, instead, sustainable strategies are adopted to gain legitimacy in the eyes of groups or individuals who influence or are influenced by the firms' activities (Freeman, 1984). In contrast, theories that focus on the relationships between organizations and resources suggest that firms implement strategies to exploit organizational effectiveness, interdependence, external control, resource position barriers, and the relationship with natural environment resources to gain a competitive advantage in the market (e.g., Hart, 1995; Pfeffer and Salancik, 1978; Wernerfelt, 1984). Taking these perspectives together, the drivers of corporate sustainability strategies can be reactive (i.e., firms engage in sustainability strategies due to external pressures, mostly unwillingly) and proactive factors (i.e., firms adopt sustainable practices driven by resources, beliefs, and motives internal to the organization) (Aguinis and Glavas, 2012).

From these theoretical points of view, recent research has identified several determinants of corporate CE strategies, such as pressures from public policy (e.g., Cainelli et al., 2020; Siedschlag et al., 2022), market demands and orientation (e.g., Cainelli et al., 2020; Schmidt et al., 2021), economic incentives and environmental commitment (e.g., Centobelli et al., 2021; Gusmerotti et al., 2019), financial resources (e.g., Kiefer et al., 2019; Triguero et al., 2022), and ethical leadership (Cheffi et al., 2023). However, studies focusing on how specific corporate governance mechanisms affect CE strategies are still scarce, despite the growing emphasis on the role of corporate governance in sustainable business policies (e.g., Sustainable Finance Action Plan - EC, 2018).

Most studies inquiring into the role of CG mechanisms on corporate sustainability have focused on environmental performance and strategies in a broader sense (e.g., Ludwig and Sassen, 2022), reporting mixed results. A stream of literature has extensively examined the role of CSR committees in executive boards in fostering green strategies. Some studies, for instance, suggest that adopting CSR committees improves the overall environmental performance of non-financial companies (e.g., Orazalin and Mahmood, 2021), in particular, greenhouse gas (GHG) emissions and carbon performance (Córdova et al., 2018; Oyewo, 2023; Saeed et al., 2021). Others, instead, argue that firms may adopt this mechanism as a mere form of ceremonial conformity, with a limited impact on corporate environmental strategies (e.g., Rodrigue et al., 2013). Academic literature further shows that firms increase their environmental commitment by setting up targeted management teams (Dangelico, 2015; Jabbour et al., 2013). Environmental (or "green") teams are workers' groups formed, either voluntarily or as part of their job responsibility, to solve environmental problems or implement programs to improve environmental performance. Taken as a whole, research suggests that such teams are effective in boosting environmental efforts at the company level, and reflect a proactive and advanced environmental management, leading to increased green performance and reputation (Dangelico, 2015; Jabbour et al., 2013).

The adherence to the UNGC principles in company management has also been associated with the adoption of green strategies. Some studies report a positive impact of adopting these principles on pollution prevention, recycling, and clean energy use (Berliner and Prakash, 2015; Ortas et al., 2015), while others question their effectiveness, raising concerns for potential "bluewashing" (e.g., Jastram and Klingenberg, 2018). Likewise, some studies support that providing economic incentives to top management can play a role in aligning executives' interests with corporate sustainability. Prior research points out that, if properly contracted, economic incentives promote long-term orientation of strategies (Flammer et al., 2019), environmental initiatives (Haque, 2017), pollution prevention (Rodrigue et al., 2013), and ultimately increase ESG performance (Baraibar-Diez et al., 2019). By contrast, other literature highlights that such a CG mechanism could stress managers' short-termism and a narrow focus on process-oriented carbon performance (e.g., Haque and Ntim, 2020).

The literature further suggests that corporate sustainability requires two-way communication with stakeholders (Freeman, 1984). Stakeholder engagement includes a broad range of processes and strategies that aim at increasing stakeholder participation, cooperation and consultation, exchanging information, and acquiring knowledge (e.g., Plaza-Úbeda et al., 2010). Some studies posit that stakeholder engagement can positively affect the definition of sustainability strategies (e.g., Ruiz et al., 2021) and improve environmental performance (Dögl and Behnam, 2015; Jang et al., 2017; Papagiannakis et al., 2019). In the same vein, stakeholders can be engaged by implementing sustainability disclosure (e.g., Romero et al., 2019). Sustainability reporting has become a cornerstone of corporate accountability, thus triggering increased levels of guidance and regulation (de Villiers et al., 2022). More and more institutions are now working to provide firms with standardized sustainability reporting principles, such as the Task Force on Climate-Related Financial Disclosure (TCFD) at the Financial Stability Board, the International Standard-Setting Board (ISSB), and the European Financial Reporting Advisory Group (EFRAG). Some studies show that reporting sustainability information encourages managers to align with societal issues (Tang and Higgins, 2022), integrating environmental, social, and governance factors into management decision-making and positively affecting the creation of environmental value (Córdova et al., 2018; Massa et al., 2015). Other studies, instead, show that sustainability reporting is more narrative compared to financial reporting and could have a limited impact on a firm's organization when it is implemented only for legitimization purposes (Barkemeyer et al., 2014).

The CG mechanisms so far identified, summarized in Table 1, represent a sub-sample of a broader universe of corporate governance practices that previous work has shown to be strictly linked to environmental sustainability strategies in a broader sense (e.g., Birindelli and Palea, 2022).

However, environmental strategies (e.g., GHG emission reduction or environmental capital expenditure) can also be implemented in "linear" business models. Instead, our study aims to investigate whether these CG mechanisms can influence the reorientation of business models towards CE. As mentioned above, we define the circular economy as a productive system aiming at resource reduction and reuse (Nobre and Tavares, 2021; Palea et al., 2023). In line with the study of Birindelli and Palea (2022) in the banking sector, we link CG mechanisms that express a sustainability orientation to the likelihood that non-financial manufacturing listed companies adopt CE strategies to answer the following research question:

RQ *Which CG mechanisms, if any, affect the likelihood that manufacturing listed companies implement CE strategies?*

Since the existing literature provides mixed evidence on the impact of these mechanisms on sustainable practices, no prediction is made on the relationship between CG mechanisms and CE practices. Moreover, it is important to note that we aim to examine whether CG mechanisms can promote the adoption of CE strategies independently from the extent to which firms go circular. Fig. 1 illustrates the conceptual framework that underlies our research, which includes other firm-specific and external factors linked to CE practices.

3. Research design

3.1. Sample

We draw our sample from the Refinitiv databases (Refinitiv, 2023) focusing on industries involved in the production and supply of physical goods. These sectors are of high interest for the CE literature and policymaking, as they can contribute to the transition towards CE by making products more durable or production processes more sustainable (EC, 2020b; 2015; Pieroni et al., 2021; Urbinati et al., 2017). Accordingly, we consider the following sectors: Materials (GICS 1510, including chemical and metal/mining firms producing raw materials, components, and semi-finished products), Capital Goods (GICS 2010, including firms producing machinery, tools, equipment, and constructions for other sectors), Automotive (GICS 2510, including consumer vehicles and components manufacturers), Consumer Durables (GICS 2520, including household, leisure, and textile durable goods), and Technology (GICS 4520 and 4530, including hardware, equipment, and semiconductors).

Our analyses include the 2010–2021 period to compare firms' behaviors before and after the significant sustainable policies events in 2015: the COP21 Conference (Paris Agreement) and the launch of the UN Sustainable Development Goals (SDGs) at a global level, as well as the implementation of the Circular Economy (CE) package in the EU. Additionally, by including 2020 and 2021 in the analysis, we can verify if and how the COVID-19 pandemic has affected the adoption of sustainable practices.

In this timeframe, we select a balanced panel of 505 firms worldwide. Adopting a balanced longitudinal panel allows us to follow how CE strategies have evolved for the same group of firms over time. Moreover, it contributes to mitigating the noise from unit heterogeneity, resulting in more sensible and robust analyses (Frees, 2004). The drawback of this research strategy is a reduction in sample size. In such a trade-off, we prioritize the more informative longitudinal analysis over the sample size which, however, consists of 6060 observations. Our final balanced sample includes firms from Europe (EU, the U.K., Switzerland, Norway), the USA, Japan, and other large economies (i.e., Australia, Canada, and China).[1] Table 2 reports the distribution of firms by sector and region.

The most represented sectors are Capital Goods (36.0%) and Materials (34.1%), while the smallest sectors are Automotive (8.5%) and Durables (9.3%). Firms are mainly located in Europe (32.7%), the USA (26.7%) and Japan (27.1%), while other countries (i.e., Australia, Canada, and China) are residual (13.5% overall).

3.2. Data

We extract data from Refinitiv Datastream, Company Fundamentals, and ESG datasets (Refinitiv, 2023). In line with the above-mentioned definition of circular economy (Nobre and Tavares, 2021), we focus on practices relating to efficient resource use, clean and renewable energy sources, and "circular" closed loops of materials. Resource efficiency practices include actions and policies to pursue *energy* and *water efficiency* goals (Demirel and Danisman, 2019), as well as *renewable energy use* and *waste reduction* (e.g. Calzolari et al., 2021). Closing loop actions include *product eco-design* (e.g., Triguero et al., 2022) and *take-back initiatives* to recover end-of-life products from consumers (e.g., Van Opstal and Borms, 2023). The mentioned actions (hereafter CE actions) are recorded in Refinitiv as a dummy variable that takes the value of one ("true") when the company implements it, zero otherwise. Unfortunately, the binary indicators provided by Refinitiv do not provide a measure of the extent, timeframe, or long-term orientation within which a company adopts actions to implement a CE strategy. Nonetheless, they allow exploring which CG mechanisms induce firms to adopt certain CE strategies.

As for CG mechanisms, we focus on those expressing a corporate sustainability orientation as identified in prior literature (e.g., Birindelli and Palea, 2022; check section 2 for a more extensive review), collecting data on i) board-level *CSR Committee*; ii) *environment management team*; iii) *UNGC signatory status*; iv) *ESG executive compensation;* v) *stakeholder engagement;* and vi) *sustainability reporting*. All data are recorded in dummy variables that take the value of one when the firm adopts the mechanism and zero otherwise.

We then account for other factors that may affect CE strategies beyond CG mechanisms, such as corporate environmental risk (proxied by *GHG intensity*), environmental policy changes (i.e., the post-*Paris Agreement* period) and stock market mechanisms (*Dow Jones Sustainability Index [DJSI] Return* and *Analyst Coverage*).

[1] Since the selected European countries participated in the European Single Market in the period under consideration, we group them as "Europe". We consider the other large economies together in a residual category because of the limited number of observations. Brazil, Russia, India, South Africa, and other G20 countries are not included in the sample due to a lack of balanced data.

Table 1
Environmental impact of corporate governance.

Governance mechanism	Reference	Region	Period	Industry	Explained variable	Main results
CSR Committee	Córdova et al. (2018)	South America	2013–2016	All industries	GHG emission reduction	Positive impact
	Orazalin and Mahmood (2021)	Europe	2009–2016	All non-financial industries	Environmental performance (environmental score from Refinitiv database + individual components, i.e., resource use, emissions, and innovation)	Positive impact
	Rodrigue et al. (2013)	US	2003–2008	Environmentally sensitive industries (SIC code between 10xx and 39xx)	Environmental regulatory performance, pollution prevention performance, intensity of environmental capital expenditures (metrics from KLD database)	No impact
	Saeed et al. (2021)	All countries	2002–2017	Energy	Environmental performance (environmental score from Refinitiv database)	Positive impact
	Oyewo (2023)	All countries	2006–2020	All non-financial industries	Carbon emission reduction	Positive impact
Environmental teams	Dangelico (2015)	US	2010	All industries	Environmental performance and reputation (US 500 Newsweek's 2010 Green Ranking)	Positive impact
	Jabbour et al. (2013)	Brazil	2005–2006	4 manufacturing companies (multiple case study)	–	The most proactive and advanced environmental management is the same company which uses green teams more intensely
UNGC membership	Berliner and Prakash (2015)	US	2000–2010	All industries	Environmental strengths and concerns (KLD database)	Positive impact on strengths. Negative impact on concerns
	Ortas et al. (2015)	Spain, France, and Japan	2008–2013	All industries	Environmental performance (score from Refinitiv database)	Positive impact
ESG executive compensation	Baraibar-Diez et al. (2019)	Europe	2005–2015	All industries	Environmental performance (score from Refinitiv database)	Positive impact
	Flammer et al. (2019)	US	2004–2013	All non-financial industries	Emission reduction, green innovations	Positive impact
	Haque (2017)	UK	2002–2014	All non-financial industries	Carbon performance (carbon reduction initiatives and GHG emissions)	Positive impact on carbon reduction initiatives. No impact on GHG emissions
	Rodrigue et al. (2013)	US	2003–2008	Environmentally sensitive industries (SIC code between 10xx and 39xx)	Environmental regulatory performance, pollution prevention performance, intensity of environmental capital expenditures (metrics from KLD database)	Some evidence of a positive impact of on pollution prevention
Stakeholder engagement	Dögl and Behnam (2015)	Germany, US, India and China	–	All industries	Green technology, green products, green strategy, green communication	Positive impact
	Jang et al. (2017)	US	2016	Restaurant	Environmental sustainability (environmental strategy, sustainable food, energy/water efficiency, waste management, reuse & recycle, and community support)	Positive impact
	Papagiannakis et al. (2019)	All countries	2003–2014	Manufacturing	Environmental product innovation (ASSET4)	The relationship between environmental management systems and environmental product innovation is positively moderated by stakeholder engagement
	Salem et al. (2017)	Libya	–	All non-financial industries	Environmental performance (scale of 11 items)	Positive impact
	Vachon and Klassen, (2008)	US and Canada	–	Package printing	Environmental performance (solid waste disposal, air emissions, water emissions)	Positive impact
Sustainability reporting	Córdova et al. (2018)	South America	2013–2016	All industries	GHG emission reduction	Positive impact
	Massa et al. (2015)	Italy	2013	One case study in entertainment industry	–	The adoption of sustainability reporting engendered environmental value creation

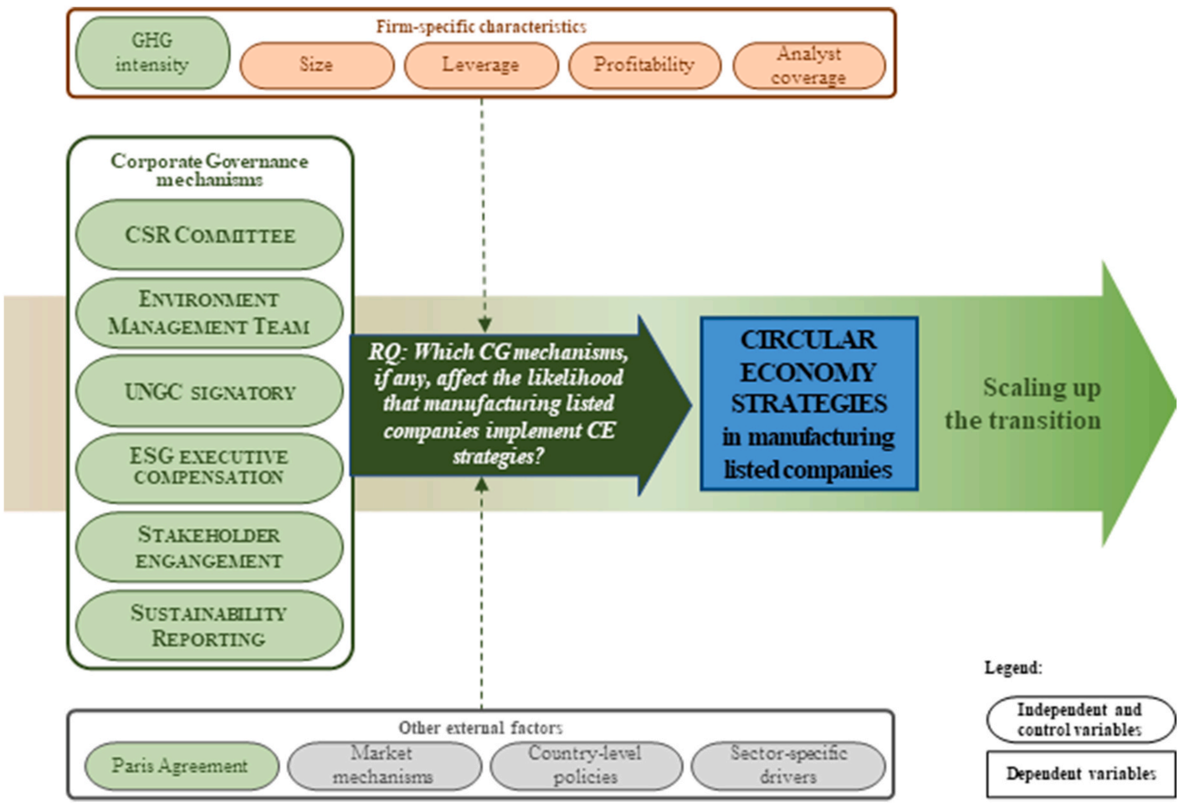

Fig. 1. Conceptual framework.

Table 2
Distribution of firms by sector and country (balanced, $T = 12$).

Number of firms	Automotive	Capital Goods	Durables	Materials	Technology	Total	% of firms
Europe	12	79	13	52	9	**165**	32.7%
USA	5	42	18	41	29	**135**	26.7%
Japan	22	45	13	37	20	**137**	27.1%
Other countries	4	16	3	42	3	**68**	13.5%
Total	**43**	**182**	**47**	**172**	**61**	**505**	100%
% of firms	8.5%	36.0%	9.3%	34.1%	12.1%	100%	

The extant literature shows that more polluting firms face higher pressure to implement CE strategies (Cadez et al., 2019). We, therefore, use the firm-level *GHG intensity* computed as the logarithm of total CO_2 equivalent emissions scaled by revenues (Aswani et al., 2023) as a proxy for a firm's exposure to environmental risk.[2] We then adopt a dummy variable *Paris Agreement* that takes the value of 0 in 2010–2014 and 1 in 2015–2021 to control for a Paris Agreement effect on CE strategies. Research indeed suggests that the Paris Agreement has represented a significant turning point for climate change awareness and public policy (Palea and Drogo, 2020). Finally, prior literature shows that stock market can influence sustainable practices (e.g., Iqbal et al., 2022). Accordingly, following Hawn et al. (2018), we condition our model on sustainable stock market performance by using the net return of the Dow Jones Sustainability World Index (DJSI) (hereafter *DJSI return*). We also control for firm-level *analyst coverage* (i.e., the number of analysts covering a security), which can impact corporate strategic decision-making processes (Brauer and Wiersema, 2018) and green innovation (Han et al., 2022).

We also control for firm-specific financial characteristics. Prior literature provides evidence that larger and more profitable firms are more prone to climate action (e.g., Hsueh, 2017), and only financially robust firms can effectively sustain green strategies (Biondi et al., 2023). Accordingly, we control for a firm's *size*, computed as the logarithm of total assets (Blasi et al., 2021); *profitability*, computed as operating income before depreciation to total assets (Palea et al., 2023); *leverage*, which is the ratio of total debt to total assets (Barros et al., 2022).

Finally, we include *sector* and *region* fixed effects to account for external pressures from policy or industry specificities (e.g., see Siedschlag et al., 2022 for a review). *Region* and *sector* are those described in the sample selection process (section 3.1) and are time-invariant. The Appendix provides a more detailed description of all variables.

Table 3 reports the descriptive statistics for the CE and CG variables included in the model. Panel A displays the proportion of firms adopting each CE action and CG mechanisms (value = 1), while Panel B reports the descriptive statistics for firms' characteristics.

Panel A shows that, among the CE actions, *energy efficiency* shows the highest frequency (83.66%), followed by *water efficiency* (64.49%) and *renewable energy use* (62.23%). *Waste reduction*, *product eco-design*, and *take-back initiatives* are adopted by 31.95%, 31.57%, and 22.48% of the firms, respectively. Firms that do not take any CE action are 8.18% of the

[2] We exclude other environmental risk proxies that could explain variations in CE strategies (e.g., water withdrawals, energy use, and waste generated) because they highly correlate with CO_2 emissions and have fewer observations.

Table 3
Descriptive statistics.

Panel A. Proportions (value = 1) of CE actions and CG mechanisms.

		Observations	%
CE actions	No action	496	8.18%
	Energy efficiency	5070	83.66%
	Water efficiency	3908	64.49%
	Renewable energy use	3771	62.23%
	Product eco-design	1974	32.57%
	Waste reduction	1936	31.95%
	Take-back initiatives	1362	22.48%
CG mechanisms	No mechanism	432	7.13%
	Sustainability reporting	4912	81.06%
	CSR committee	4543	74.96%
	Environment management team	4445	73.35%
	Stakeholder engagement	3113	51.37%
	ESG executive compensation	2063	34.04%
	UNGC signatory	2011	33.18%

Panel B. Descriptive statistics of firm's characteristics.

Variable	Observations	Min	Max	Median	Mean	SD
Firm size	6060	19.373	26.144	22.495	22.574	1.2427
Profitability	6060	−0.075	0.415	0.109	0.116	0.0630
Leverage	6060	0.0004	0.725	0.231	0.242	0.1389
GHG intensity	4769	3.47e-04	5.630	0.066	0.350	0.7500

Notes: Firms: 505. Firm-year observations: 6060. All control variables are winsorized at the 1% level (two-sided) by year. All variables are defined in Section 3.2 and the Appendix.

sample. Concerning CG mechanisms, *sustainability reporting* (81.06%), *CSR committee* (74.96%) and *environment management team* (73.35%) are the most frequent among firms, followed by *stakeholder engagement* (51.37%). In contrast, only 33.18% of firms are *UNGC signatories*, while 34.04% adopted *ESG executive compensation* schemes. Only 7.13% of observations do not adopt any of the CG mechanisms considered. As Panel B shows, only 79.07% of firms report their *GHG intensity*. This makes the number of observations in the regression decrease from 5555 to 4333.

3.3. CE strategies identification

To identify CE strategies, we examine the correlation coefficients among the above-described CE actions and detect which correlate the most. We then perform a Principal Component Analysis (PCA) as a robustness check which corroborates our reduction of CE actions to a smaller set of strategies. Table 4, Panel A, reports the correlation matrix, while Panel B displays the results from the PCA.

As Panel A shows, *waste reduction* and *renewable energy use* highly correlate with *energy efficiency* and *water efficiency* items ($\rho > 0.60$), which is consistent with these items representing resource efficiency actions (e.g., Bocken et al., 2016). Differently, *product eco-design* and *take-back initiatives* show both lower but significant correlations with other items ($\rho < 0.5$) and between them ($\rho = 0.53$), which suggests that such actions can be taken independently from one another.

Panel B reports the PCA results. Based on a scree test (Cattell, 1966), we retain 3 Principal Components, which cumulatively explain more than 80% of the total variance (Hair et al., 2013). The rotated component matrix displayed in Panel B shows that the first component loads on *energy efficiency, water efficiency, renewable energy use,* and *waste reduction.* These actions pursue a resource reduction goal, so we will refer to them as "efficiency" actions. *Product eco-design* and *takeback initiatives*, instead, load on two separate components. For this reason, we keep them separated in our analyses but refer to them as "closing loop" actions.

In line with these findings, we determine firms' CE strategies based on the presence of the above-mentioned CE actions. Since the adoption of sustainable practices is generally progressive (Urbinati et al., 2017), we identify different levels of CE strategies characterized by an increasing level of commitment to the CE paradigm. We start with

Table 4
CE strategies definition.

Panel A. Correlation Matrix of CE actions

	(1)	(2)	(3)	(4)	(5)	(6)
(1) Energy efficiency	1					
(2) Water efficiency	**0.7687***	1				
(3) Renewable energy use	0.6247*	**0.7348***	1			
(4) Waste reduction	**0.6860***	**0.7739***	0.6451*	1		
(5) Product eco-design	0.3405*	0.4549*	0.3970*	0.4565*	1	
(6) Take-back initiatives	0.3544*	0.4125*	0.4157*	0.5293*	0.5273*	1

Panel B. Principal Component Analysis (rotated) for CE actions

Component	Total variance explained	Proportion	Cumulative
1	3.0808	51.35%	51.35%
2	1.1639	19.40%	70.75%
3	1.0112	16.85%	87.60%
Variable	**Component 1**	**Component 2**	**Component 3**
Energy efficiency	0.5352		
Water efficiency	0.5492		
Renewable energy use	0.6006		
Waste reduction	0.5332		
Take-back initiatives		0.9626	
Product eco-design			0.9923

Notes: *Tetrachoric correlation p-value <0.01 (two-tailed). The coefficients in bold are $\rho > 0.667$. N = 6060.
Tests for suitability of PCA analysis: KMO value ≈ 0.8487. Bartlett's test of sphericity χ^2 (15) = 7102.62 (p-value <0.001). The PCA is meritorious (Hair et al., 2013). Rotation method: Promax (oblique) with Kaiser normalisation. Varimax (orthogonal) rotation yields comparable results. Loadings below 0.30 are suppressed (Hair et al., 2013, p. 115). All variables are defined in Section 3.2 and the Appendix.

resource efficiency (Bocken et al., 2016), moving up to closing loop actions (e.g., Triguero et al., 2022). We identify the following active CE strategies: (1) “*At least one efficiency action*”; (2) “*All efficiency actions*”; (3) “*All efficiency actions + product eco-design*”; (4) “*All efficiency actions + takeback initiatives*”; (5) “*All efficiency and closing loop actions*”. Each firm falls in one of the above strategies depending on which CE actions it implements in the year under consideration. Firms that do not implement any CE action are categorized into **Strategy (0) “*No CE action*”** (i.e., all CE actions value = 0).

To transition to a CE paradigm, it is essential for non-financial companies to first enhance resource efficiency and maximize their value during the production phase (Van Berkel and Fadeeva, 2020). Accordingly, **Strategy (1) “*At least one efficiency action*”,** includes firms at an earlier stage of circularity, adopting up to three out of four “efficiency” actions; **Strategy (2) “*All efficiency actions*”** includes firms implementing all efficiency actions. Firms in both Strategies (1) and (2) do not implement *product eco-design* and *take-back initiatives*.

Firms at a higher level of circularity focus on materials used in their products or empower consumers to close the loop (Urbinati et al., 2017). Accordingly, **Strategy (3) “*All efficiency actions* + *product eco-design*”** includes firms implementing *product eco-design* along with all “efficiency” actions; **Strategy (4) “*All efficiency actions* + *take-back initiatives*”** includes firms implementing *take-back initiatives* along with all “efficiency” actions. Finally, **Strategy (5) “*All efficiency and closing loop actions*”** includes firms adopting all the actions.

All firms implementing other combinations of CE actions are grouped under a “residual” category, and their results remain untabulated.

3.4. Empirical model

To investigate which CG mechanisms increase the likelihood of adopting CE strategies, as identified in the previous section, we perform the following multinomial logistic regression:

$$\begin{aligned}\log\frac{P(CE\ Strategy_{it}=x)}{P(CE\ Strategy_{it}=0)} &= \beta_0+\sum\nolimits_{n=1}^{6}\beta_{n,x}CG\ mechanisms_{i,t-1}\\ &+\beta_{7,x}ParisAgreement_t+\beta_{8,x}DJSIreturn_{t-1}\\ &+\beta_{9,x}ParisAgreement_t\times DJSIreturn_{t-1}\\ &+\beta_{10,x}AnalystCoverage_{i,t-1}\\ &+\beta_{11,x}GHG\ intensity_{i,t-1}\\ &+\sum\nolimits_{n=12}^{14}\beta_{n,x}financial\ controls_{i,t-1}+\beta_{15,x}region_i\\ &+\beta_{16,x}sector_i+\varepsilon_{i,x}\end{aligned} \tag{1}$$

CE strategy is one of the five strategy levels adopted by the firm *i* at time *t*. We use Strategy (0) “No CE action” as the reference category. *CG mechanisms* are *sustainability reporting*, *CSR committee*, *environment management team*, *stakeholder engagement*, *ESG executive compensation*, and *UNGC signatory*, which take the value of one when the mechanism is there, zero otherwise. *ParisAgreement* takes the values of 0 up to 2014 and 1 from 2015. *DJSIreturn* is the net return of the Dow Jones Sustainability Index World. *ParisAgreement* × *DJSIreturn* is an interaction term that controls for differences in *DJSIreturn* due to *ParisAgreement*. *AnalystCoverage* is the number of analysts covering the security of the firm. *GHG intensity* is the Logarithm of Total CO_2 Equivalent Emissions

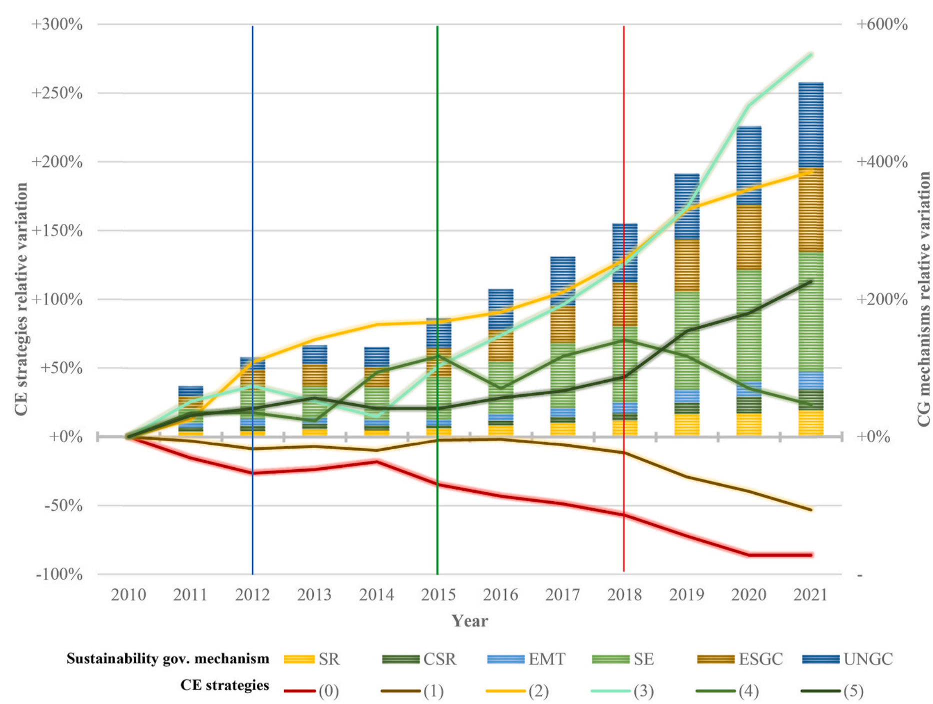

Fig. 2. CE strategies and CG mechanisms trend (variation from 2010) – All Regions
Notes: a) Percent variation from year 2010. Left axis refers to Strategy (0)–(5) trends. Right axis refers to CG mechanisms cumulative trend. **b)** SR *is sustainability reporting*. CSR is *CSR committee*. EMT is *environment management team*. SE is *stakeholder engagement*. ESGC is *ESG executive compensation*. UNGC is *UNGC signatory*. **c) Strategy (0)**: all variables value = 0; **Strategy (1):** *energy efficiency, water efficiency, renewable energy use,* or *waste reduction value* = 1 (at least one out of four), *product eco-design* and *take-back initiatives* value = 0; **Strategy (2):** *energy efficiency, water efficiency, renewable energy use,* and *waste reduction* values = 1, *product eco-design* and *take-back initiatives value* = 0; **Strategy (3):** *energy efficiency, water efficiency, renewable energy use, waste reduction,* and *product eco-design values* = 1, *take-back initiatives* value = 0; **Strategy (4):** *energy efficiency, water efficiency, renewable energy use, waste reduction,* and *take-back initiatives values* = 1, *product eco-design* value = 0; **Strategy (5):** *energy efficiency, water efficiency, renewable energy use, waste reduction, product eco-design,* and *take-back initiatives* values = 1. **d)** The blue vertical line is the 2012 UN conference in Rio de Janeiro ; the green vertical line is the Paris Agreement ratification and UN SDGs launch (2015); the red vertical line is the Special Report on Global Warming of the IPCC (SR15 - 2018). All variables are defined in the appendix. All strategies are defined in Table 4 and Section 3.3. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

to Revenues ratio. *Financial controls* include firm *size*, *profitability* (ROA) and debt *leverage* (Total Debt to Total Assets ratio). *Region* and *sector* identify a firm's *i* geographical area and industry group. We adopt the first lag of *CG mechanisms*, *GHG intensity*, and *financial controls* to set the direction of the correlation (Birindelli and Palea, 2022) and cluster standard errors at the firm level to account for unobserved heterogeneity (Petersen, 2009).

4. Descriptive analysis

Fig. 2 portrays the global time-trends of CE strategies (lines) and CG mechanisms (stacked bars). Since we adopt a balanced data panel, our statistics show how the same companies have changed their strategies and mechanisms over time.

The graph shows that CE strategies and CG mechanisms grew at similar paces, along with an increasing awareness of policymakers towards climate change and environmental issues. Interestingly, Strategy (2) "*All efficiency actions*" and the proportion of *UNGC signatory* firms increased after 2012, after the UN Conference on Sustainable Development in Rio de Janeiro. The Paris Agreement and the launch of the SDGs (2015) also represented a turning point for the implementation of Strategy (3) "*All efficiency actions + product eco-design*" and the diffusion of different CG mechanisms at the expense of Strategies (0) "*No CE action*" and (1) "*At least one efficiency action*". Furthermore, the adoption of Strategies (2) "*All efficiency actions*", (3) "*All efficiency actions + product eco-design*", and (5) "*All efficiency and closing loop actions*", and CG mechanisms greatly spread among firms after 2018, when the Intergovernmental Panel on Climate Change (IPCC) published its "Special Report on Global Warming of 1.5 °C", and the EU adopted the Action Plan on Sustainable Finance. Such evidence points to the importance of policymakers' commitment to fighting climate change as a driver for changes in firms' behaviours. The COVID-19 pandemic, instead, did not appear to hinder the diffusion of CE actions and CG mechanisms. Despite various governments' restrictions, the growth of these actions has not been reverted or slowed down significantly.

Table 5 displays the sample distribution by CE strategy, year, and

Table 5
Strategy type proportion (value = 1) by year and region.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
(0) No CE action													
Observations	*72*	*61*	*53*	*55*	*59*	*47*	*41*	*37*	*31*	*20*	*10*	*10*	***496***
All regions	14.3	12.1	10.5	10.9	11.7	9.3	8.1	7.3	6.1	4.0	2.0	2.0	**8.2**
Europe	4.8	3.6	1.8	3.0	4.2	1.8	1.2	0.0	0.0	0.0	0.0	0.0	**1.8**
USA	20.7	17.8	15.6	16.3	16.3	14.8	15.6	14.1	13.3	8.9	3.7	3.0	**13.3**
Japan	8.0	8.0	8.0	8.8	9.5	8.0	5.8	6.6	4.4	3.6	2.2	2.9	**6.3**
Other countries	36.8	29.4	26.5	23.5	25.0	19.1	14.7	13.2	8.8	4.4	2.9	2.9	**17.3**
Pearson's χ^2 *(across regions, 3 d.f.)* 263.01 ($p < 0.001$); *(across years, 11 d.f.)* 119.60 ($p < 0.001$)													
(1) At least one efficiency action													
Observations	*171*	*166*	*156*	*159*	*154*	*167*	*168*	*161*	*151*	*121*	*103*	*80*	***1757***
All regions	33.9	32.9	30.9	31.5	30.5	33.1	33.3	31.9	29.9	24.0	20.4	15.8	**29.0**
Europe	32.1	29.1	30.3	32.1	32.1	33.3	33.3	31.5	27.9	21.2	16.4	13.9	**27.8**
USA	35.6	35.6	31.9	30.4	30.4	31.9	28.9	27.4	25.2	20.7	21.5	12.6	**27.7**
Japan	35.0	32.1	26.3	25.5	24.1	27.0	28.5	27.0	28.5	23.4	17.5	15.3	**25.9**
Other countries	32.4	38.2	39.7	44.1	39.7	47.1	51.5	51.5	47.1	38.2	33.8	27.9	**40.9**
Pearson's χ^2 *(across regions, 3 d.f.)* 67.20 ($p < 0.001$); *(across years, 11 d.f.)* 90.04 ($p < 0.001$)													
(2) All efficiency actions													
Observations	*55*	*62*	*85*	*94*	*100*	*101*	*105*	*113*	*126*	*146*	*154*	*161*	***1302***
All regions	10.9	12.3	16.8	18.6	19.8	20.0	20.8	22.4	25.0	28.9	30.5	31.9	**21.5**
Europe	17.0	20.0	21.2	23.0	24.8	26.1	26.7	29.1	30.9	32.7	32.1	31.5	**26.3**
USA	6.7	5.9	14.8	16.3	17.0	15.6	17.8	18.5	21.5	25.9	28.1	32.6	**18.4**
Japan	4.4	5.8	10.2	13.9	15.3	16.8	17.5	17.5	19.0	21.2	24.8	24.1	**15.9**
Other countries	17.6	19.1	23.5	22.1	22.1	20.6	19.1	23.5	29.4	41.2	42.6	47.1	**27.3**
Pearson's χ^2 *(across regions, 3 d.f.)* 83.14 ($p < 0.001$); *(across years, 11 d.f.)* 146.58 ($p < 0.001$)													
(3) All efficiency actions + product eco-design													
Observations	*27*	*34*	*37*	*34*	*31*	*41*	*47*	*53*	*61*	*72*	*92*	*102*	***631***
All regions	5.3	6.7	7.3	6.7	6.1	8.1	9.3	10.5	12.1	14.3	18.2	20.2	**10.4**
Europe	9.1	11.5	13.9	12.7	9.7	12.1	12.1	13.3	15.8	20.6	24.2	24.8	**15.0**
USA	2.2	3.0	3.0	3.0	3.0	5.2	5.9	6.7	8.1	9.6	15.6	18.5	**7.0**
Japan	5.1	7.3	6.6	5.8	6.6	8.0	10.2	12.4	13.1	13.9	16.8	20.4	**10.5**
Other countries	2.9	1.5	1.5	1.5	2.9	4.4	7.4	7.4	8.8	8.8	11.8	11.8	**5.9**
Pearson's χ^2 *(across regions, 3 d.f.)* 83.16 ($p < 0.001$); *(across years, 11 d.f.)* 141.44 ($p < 0.001$)													
(4) All efficiency actions + take-back initiatives													
Observations	*17*	*20*	*20*	*19*	*25*	*27*	*23*	*27*	*29*	*27*	*23*	*21*	***278***
All regions	3.4	4.0	4.0	3.8	5.0	5.3	4.6	5.3	5.7	5.3	4.6	4.2	**4.6**
Europe	4.8	3.6	4.2	4.2	6.7	6.1	4.8	5.5	6.1	4.8	4.2	3.6	**4.9**
USA	3.7	5.2	4.4	4.4	4.4	5.9	4.4	6.7	7.4	7.4	5.9	5.9	**5.5**
Japan	2.9	5.1	5.1	4.4	5.1	5.8	5.8	6.6	5.8	6.6	5.8	5.1	**5.4**
Other countries	0.0	0.0	0.0	0.0	1.5	1.5	1.5	0.0	1.5	0.0	0.0	0.0	**0.5**
Pearson's χ^2 *(across regions, 3 d.f.)* 36.98 ($p < 0.001$); *(across years, 11 d.f.)* 7.31 ($p = 0.773$)													
(5) All efficiency and closing loop actions													
Observations	*39*	*45*	*47*	*50*	*47*	*47*	*50*	*52*	*56*	*69*	*74*	*83*	***659***
All regions	7.7	8.9	9.3	9.9	9.3	9.3	9.9	10.3	11.1	13.7	14.7	16.4	**10.9**
Europe	7.3	10.3	11.5	12.7	11.5	11.5	11.5	11.5	11.5	13.3	15.2	17.6	**12.1**
USA	7.4	7.4	6.7	6.7	7.4	7.4	8.1	8.1	10.4	13.3	14.1	17.0	**9.5**
Japan	10.9	10.9	12.4	13.1	11.7	11.7	13.1	14.6	15.3	18.2	19.0	19.7	**14.2**
Other countries	2.9	4.4	2.9	2.9	2.9	2.9	2.9	2.9	2.9	5.9	5.9	5.9	**3.8**
Pearson's χ^2 *(across regions, 3 d.f.)* 67.59 ($p < 0.001$); *(across years, 11 d.f.)* 39.82 ($p < 0.001$)													

Notes: Post hoc comparison of strategies proportions before and after 2015 (Paris Agreement) are negative in Strategies (0) and (1), *p*-values <0.001. The effect is positive for Strategies (2), (3), and (5), *p*-values <0.001. The effect is positive but negligible for Strategy (4), *p*-value = 0.065. All strategies are defined in Table 4 and Section 3.3.

region.

Data shows that the adoption of more complex CE strategies has increased over time in all countries. Firms implementing Strategy (0) "*No CE action*", which represented globally 14.3% in 2010, steadily decreased to 2.0% in 2020 and 2021. Strategy (0) declined importantly in the USA and Other Countries, dropping from 20.7% to 36.8% in 2010 to 3.0% and 2.9% in 2021, respectively. Interestingly, no firms in Europe implemented Strategy (0) in 2017–2021.

Similarly, Strategy (1) "*At least one efficiency action*" decreased from 33.9% in 2010 to 15.8% in 2021. The decrease across the different regions progressed at different paces, starting in 2016 in the USA, 2017 in other countries, 2018 in Europe, and 2019 in Japan. These trends can be an effect of the Paris Agreement and the SDGs adoption, which represented a milestone in the sustainability regulatory framework for firms worldwide and stimulated the pursuit of resource efficiency strategies, at least. In fact, Strategy (2) "*All efficiency actions*" increased across all regions growing from 10.9% in 2010 to 20.8% in 2016 and 31.9% in 2021. The largest growth was in Japan and the USA, from 4.4% to 6.7% in 2010 to 24.1% and 32.6% in 2021, respectively. In Europe, however, Strategy (2) peaked at 32.7% in 2019, then fell in the subsequent years, probably as an effect of the adoption of the EU Green Deal (EC, 2019) and the new CE Action Plan (EC, 2020a).

Strategy (3) "*All efficiency actions + product eco-design*" grew across all regions in the observed period. In Europe, it increased from 9.1% in 2010 to 24.8% in 2021, while in the USA, from 2.2% in 2010 to 18.5% in 2021. Strategy (4) "*All efficiency actions + take-back initiatives*", which represents 4.6% of our sample, seems to be residual. Finally, Strategy (5) "*All efficiency and closing loop actions*" globally increased from 7.7% in 2010 to 16.4% in 2021, with the greatest growth occurring after 2017. European firms show the highest overall increment of Strategy (5), which moved from 7.3% in 2010 to 11.5% in 2018 and 17.6% in 2021. In contrast, the number of firms adopting Strategy (5) in the USA stagnated until 2017 at around 8% and then increased up to 17.0% in 2021. Again, time-trends for Strategy (5) can be linked to increasing pressure to meet stakeholders' and policymakers' requirements for the transition towards more sustainable businesses.

Table 6 reports the distribution of CG mechanisms by region and year. Each governance mechanism increased substantially during

Table 6
CG mechanisms proportion (value = 1) by year and region.

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Sustainability reporting														
Observations		*348*	*372*	*376*	*385*	*381*	*390*	*404*	*416*	*429*	*461*	*467*	*483*	***4912***
% in:	All regions	68.9	73.7	74.5	76.2	75.4	77.2	80.0	82.4	85.0	91.3	92.5	95.6	**81.1**
	Europe	86.7	89.1	92.1	92.1	92.7	93.3	94.5	97.6	98.2	98.2	98.2	98.2	**94.2**
	USA	46.7	55.6	51.9	56.3	50.4	54.8	57.8	59.3	62.2	78.5	83.0	92.6	**62.4**
	Japan	78.1	82.5	86.1	87.6	89.1	88.3	90.5	92.0	94.2	94.2	94.2	95.6	**89.4**
	Other countries	51.5	54.4	52.9	54.4	55.9	60.3	67.6	72.1	79.4	94.1	94.1	95.6	**69.4**
Pearson's χ^2 *(across regions, 3 d.f.)* 735.52 ($p < 0.001$); *(across years, 11 d.f.)* 256.84 ($p < 0.001$)														
CSR committee														
Observations		*340*	*363*	*368*	*368*	*365*	*356*	*365*	*373*	*379*	*399*	*423*	*444*	***4543***
% in:	All regions	67.3	71.9	72.9	72.9	72.3	70.5	72.3	73.9	75.0	79.0	83.8	87.9	**75.0**
	Europe	75.2	78.8	81.2	78.8	79.4	76.4	77.0	77.6	80.0	84.8	86.7	89.7	**80.5**
	USA	54.8	57.8	57.0	58.5	57.8	54.8	59.3	60.0	60.7	65.9	74.8	82.2	**62.0**
	Japan	70.8	78.8	79.6	81.0	81.0	81.8	82.5	83.9	84.7	85.4	89.1	92.0	**82.5**
	Other countries	66.2	69.1	70.6	70.6	66.2	64.7	66.2	72.1	72.1	77.9	83.8	86.8	**72.2**
Pearson's χ^2 *(across regions, 3 d.f.)* 231.12 ($p < 0.001$); *(across years, 11 d.f.)* 110.61 ($p < 0.001$)														
Environment management team														
Observations		*330*	*353*	*364*	*360*	*356*	*357*	*362*	*372*	*381*	*393*	*403*	*414*	***4445***
% in:	All regions	65.3	69.9	72.1	71.3	70.5	70.7	71.7	73.7	75.4	77.8	79.8	82.0	**73.3**
	Europe	72.7	75.8	78.2	75.2	73.3	72.7	73.3	76.4	78.2	78.2	80.6	78.8	**76.1**
	USA	57.0	62.2	63.7	64.4	65.2	68.9	71.1	70.4	70.4	74.8	77.8	82.2	**69.0**
	Japan	73.0	78.8	80.3	81.0	80.3	78.8	78.8	81.8	83.9	84.7	85.4	86.9	**81.1**
	Other countries	48.5	52.9	57.4	55.9	54.4	52.9	54.4	57.4	61.8	69.1	70.6	79.4	**59.6**
Pearson's χ^2 *(across regions, 3 d.f.)* 153.79 ($p < 0.001$); *(across years, 11 d.f.)* 62.11 ($p < 0.001$)														
Stakeholder engagement														
Observations		*143*	*172*	*202*	*208*	*211*	*232*	*252*	*279*	*301*	*346*	*375*	*392*	***3113***
% in:	All regions	28.3	34.1	40.0	41.2	41.8	45.9	49.9	55.2	59.6	68.5	74.3	77.6	**51.4**
	Europe	41.2	47.3	58.8	61.8	62.4	66.7	68.5	72.7	75.8	82.4	88.5	89.1	**67.9**
	USA	23.7	28.1	28.1	27.4	27.4	29.6	31.9	36.3	40.0	50.4	57.0	64.4	**37.0**
	Japan	21.2	29.2	35.0	35.0	35.8	42.3	47.4	54.0	59.1	68.6	72.3	75.2	**47.9**
	Other countries	20.6	23.5	27.9	30.9	32.4	35.3	45.6	52.9	60.3	70.6	77.9	80.9	**46.6**
Pearson's χ^2 *(across regions, 3 d.f.)* 365.87.0111 ($p < 0.001$); *(across years, 11 d.f.)* 561.47 ($p < 0.001$)														
ESG executive compensation														
Observations		*114*	*135*	*148*	*151*	*147*	*162*	*167*	*175*	*187*	*201*	*222*	*254*	***2063***
% in:	All regions	22.6	26.7	29.3	29.9	29.1	32.1	33.1	34.7	37.0	39.8	44.0	50.3	**34.0**
	Europe	24.8	30.3	34.5	35.8	34.5	40.6	41.8	44.2	50.3	57.0	64.2	75.2	**44.4**
	USA	35.6	41.5	43.7	43.0	42.2	42.2	42.2	41.5	42.2	43.0	45.2	50.4	**42.7**
	Japan	0.0	0.7	0.7	0.7	0.7	0.7	2.2	2.9	2.9	4.4	8.0	13.1	**3.1**
	Other countries	36.8	41.2	45.6	48.5	47.1	54.4	55.9	61.8	63.2	63.2	64.7	64.7	**53.9**
Pearson's χ^2 *(across regions, 3 d.f.)* 994.21 ($p < 0.001$); *(across years, 11 d.f.)* 148.15 ($p < 0.001$)														
UNGC signatory														
Observations		*107*	*122*	*126*	*136*	*138*	*153*	*170*	*183*	*198*	*209*	*229*	*240*	***2011***
% in:	All regions	21.2	24.2	25.0	26.9	27.3	30.3	33.7	36.2	39.2	41.4	45.3	47.5	**33.2**
	Europe	40.0	43.6	44.2	47.9	48.5	52.1	54.5	56.4	59.4	60.6	64.2	67.3	**53.2**
	USA	5.9	7.4	8.1	8.1	8.9	10.4	14.8	16.3	20.0	22.2	26.7	27.4	**14.7**
	Japan	16.8	21.9	23.4	26.3	27.0	32.1	35.8	39.4	41.6	45.3	48.9	51.1	**34.1**
	Other countries	14.7	14.7	14.7	14.7	13.2	13.2	16.2	20.6	23.5	25.0	29.4	32.4	**19.4**
Pearson's χ^2 *(across regions, 3 d.f.)* 679.75 ($p < 0.001$); *(across years, 11 d.f.)* 191.68 ($p < 0.001$)														

Notes: Post hoc comparison of CG mechanisms proportions before and after 2015 (Paris Agreement) are positive and statistically significant (p-values <0.001). All variables are defined in Section 3.2 and the appendix.

2010–2021, albeit with statistically significant differences across time and regions. As shown in Table 6, *sustainability reporting* has been the most widely adopted mechanism in each year, closely followed by *CSR committee* and *environment management teams*. At the same time, the least widely adopted mechanisms have been *stakeholder engagement*, *ESG executive compensation*, and *UNGC signatory*. This suggests that *sustainability reporting*, *CSR committee*, and *environment management teams* tend to be adopted before than other mechanisms.

At a global level, the adoption of *sustainability reporting* greatly increased from 68.9% in 2010 to 95.6% in 2021. Other Countries show the largest relative growth (from 51.15% in 2010 to 95.6% in 2021). Firms drawing up *sustainability reporting* in Europe reached 98.2% in 2021, which is the highest percentage across regions and years. Firms with a *CSR committee* increased from 67.3% in 2010 to 87.9% in 2021 globally. The USA shows the smallest percentage each year, peaking at 82.2% in 2021, while, in the same year, Japan and Europe show larger percentages of 92.0% and 89.7%, respectively.

The *environment management team* mechanism increased relatively less from 65.3% in 2010 to 82% in 2021 worldwide. The largest percentage of firms is in Japan (86.9% in 2021). In Europe, firms with *environment management teams* grew from 72.7% in 2010 to 78.8% in 2021, with a small overall increase in the period considered. Other countries show the largest increase, from 48.5% in 2010 to 79.4% in 2021. *Stakeholder engagement* grew the most, compared to other CG mechanisms, increasing threefold from 28.3% in 2010 to 77.6% in 2021 at a global level. In Europe, it increased from 41.2% in 2010 to 89.1% in 2021, while relatively lower values are observed in the USA (23.7% in 2010 and 64.4% in 2021). The other CG mechanisms increased less. The percentage of firms contracting *ESG executive compensation* grew steadily from 22.6% in 2010 to 50.3% in 2021. This policy is mainly adopted in Europe (75.2% in 2021), while Japanese firms show the least level of adoption (13.1% in 2021). Finally, the percentage of *UNGC signatory* firms more than doubled, from 21.2% in 2010 to 47.5% in 2021. European firms show the largest value (67.3% in 2021), while observations are considerably lower in the USA (27.4% in 2021).

Finally, Table 7 displays the distribution of CG mechanisms by CE strategy. Since we are analyzing the effect of governance mechanisms on circular strategies, CG mechanisms values are lagged by one year in specifying the direction of the relationship (Birindelli and Palea, 2022; Palea et al., 2023). Our descriptive analysis suggests that CG mechanisms play a role in fostering the adoption of CE strategies. In fact, more complex CE strategies are characterized by a higher presence of CG mechanisms. For instance, 77.54% of firms adopting Strategy (5), which includes all six CE actions, implement *stakeholder engagement* practices, which is 64.1 times higher than the 1.21% of firms adopting Strategy (0). The same holds for *UNGC signatory* (22.5 times higher), *sustainability reporting* (8.1 times higher), *environment management team* (5.9 times higher), *CSR Committee* (3.4 times), and *ESG executive compensation* (1.3 times higher). The *environment management team* and the *UNGC signatory* mechanisms count a larger proportion of firms in the case of Strategy (3), whereas *stakeholder engagement*, *sustainability reporting, CSR Committee*, and *ESG executive compensation* exhibit more firms in Strategy (4). Results also show that proportions in Strategies (2) and (3) are greater than in Strategy (1). Post-hoc analyses confirm that differences are statistically significant.

5. Results and discussion

5.1. Multinomial logistic regression

Table 8 reports the results from the multinomial logistic regression. The likelihood ratio chi-square test comparing the full against the null model (χ^2 (126 d. f.) = 959.65, p-value <0.001) is statistically significant. The pseudo-R^2 (Nagelkerke) of Equation (1) is 0.202 compared to the 0.157 of a model excluding CG mechanisms, which is in line with other studies (e.g., Palea et al., 2023). Table 8 displays the odds ratios for each strategy compared to Strategy (0) "*No CE action*".

Regression results suggest that some of the CG mechanisms promote the adoption of more complex CE strategies, while others seem more symbolic. The coefficients on *sustainability reporting, environment management team,* and *stakeholder engagement* are greater than one and significant for all strategies, indicating that they have an impact on the likelihood that firms adopt more complex CE strategies. Results in Column 1 suggest that firms with *sustainability reporting, environment management team*, and *stakeholder engagement* have respectively 6.139 times (p-value<0.001), 4.190 times (p-value<0.001), and 15.023 times (p-value = 0.016) higher odds of adopting Strategy (1) rather than Strategy (0). *Sustainability reporting* increases the odds of firms adopting Strategies (2), (3), (4), and (5), respectively of 14.771 times, 18.501 times, 27.225 times, and 10.896 times, p-values≤0.001, each compared to Strategy (0). The *environment management team* mechanism greatly increases the odds of firms implementing Strategies (3) (coefficient 19.685, p-value<0.001) and (5) (coefficient 12.618, p-value<0.001) compared to Strategy (0). Alongside this, the coefficients on *stakeholder engagement* further increase along with the complexity of CE strategies. The odds ratios in Strategies (4) and (5) (53.144 and 48.812, respectively, p-values = 0.001) are one and a half times higher than Strategies (2) and (3) and almost four times that in Strategy (1). Results from

Table 7
CG mechanisms by CE strategy (%).

CE strategy	(0) No CE action	(1) At least one efficiency action	All efficiency +			(5) All efficiency and closing loop actions	χ^2 (6 df) (p-value)
			(2) No closing loop actions	(3) Product eco-design	(4) Take-back Initiatives		
Sustainability reporting[a]	12.10	70.52	94.78	95.56	98.20	97.72	1.90 E+03 (<0.001)
CSR Committee[b]	28.30	62.61	84.76	84.27	91.95	96.61	881.837 (<0.001)
Environment management team[c]	15.73	61.01	81.72	90.49	87.05	92.87	1.20 E+03 (<0.001)
Stakeholder engagement[d]	1.21	28.86	68.66	68.30	77.34	77.54	1.50 E+03 (<0.001)
ESG executive compensation[e]	22.98	30.79	40.02	33.44	44.24	29.44	130.079 (<0.001)
UNGC signatory[f]	2.620	15.99	39.17	47.07	40.29	59.03	800.890 (<0.001)
Observations	*496*	*1757*	*1302*	*631*	*278*	*659*	

Note: One-year lag of CG mechanisms has been considered to set the temporal direction of the correlation. Non-significant (p-value>0.05) proportion comparisons (Bonferroni correction) **a)** ***sustainability reporting*:** (2)-(3)-(4)-(5); **b)** ***CSR committee*:** (2)-(3)-(4); (4) and (5). **c)** ***environment management team*:** (2) and (4); (3)-(4)-(5). **d)** ***stakeholder engagement*:** (2)-(3)-(4); (4) and (5). **e)** ***ESG executive compensation*:** (0) and (5); (1)-(3)-(5); (2) and (3); (2) and (4). **f)** ***UNGC signatory*:** (2) and (4); (3) and (4). All variables are defined in the appendix. All strategies are defined in Table 4 and Section 3.3.

Table 8
Results of the multinominal logistic regression.

CE strategy Odds-ratio against Strategy (0)	(1) At least one efficiency action	All efficiency actions +			(5) All efficiency and closing loop actions
		(2) No closing loop actions	(3) Product eco-design	(4) Take-back Initiatives	
CG mechanisms					
Sustainability reporting	6.139	14.771	18.501	27.225	10.896
	(<.001)	(<.001)	(<.001)	(<.001)	(0.001)
CSR committee	0.450	0.642	0.452	0.662	1.488
	(0.092)	(0.378)	(0.165)	(0.526)	(0.537)
Environment management team	4.190	7.192	19.685	8.588	12.618
	(0.001)	(<.001)	(<.001)	(<.001)	(<.001)
Stakeholder engagement	15.023	33.406	29.991	53.144	48.812
	(0.016)	(0.002)	(0.003)	(0.001)	(0.001)
ESG executive compensation	1.343	1.210	1.200	2.378	1.041
	(0.640)	(0.774)	(0.789)	(0.239)	(0.955)
UNGC signatory	0.480	0.784	1.097	0.707	1.730
	(0.212)	(0.695)	(0.886)	(0.628)	(0.407)
Control variables					
Paris Agreement	4.911	6.442	12.812	5.683	7.362
	(0.001)	(<.001)	(<.001)	(0.002)	(<.001)
DJSI return x P.A. = 0	0.649	0.742	0.413	0.626	0.445
	(0.465)	(0.614)	(0.154)	(0.465)	(0.182)
DJSI return x P.A. = 1	4.013	6.803	14.484	5.796	12.492
	(0.089)	(0.019)	(0.002)	(0.041)	(0.002)
Analyst coverage	1.201	1.554	1.408	1.923	1.716
	(0.547)	(0.183)	(0.322)	(0.081)	(0.127)
GHG intensity	1.836	2.490	2.190	3.493	2.139
	(0.012)	(0.001)	(0.006)	(<.001)	(0.015)
Firm Size	2.524	3.569	3.961	5.005	6.420
	(0.055)	(0.013)	(0.010)	(0.004)	(<.001)
Profitability	1.719	1.851	1.523	1.655	2.069
	(0.017)	(0.010)	(0.111)	(0.061)	(0.006)
Leverage	0.870	0.731	0.719	0.550	0.655
	(0.515)	(0.190)	(0.198)	(0.036)	(0.108)
Region:					
Europe	5.786	4.664	6.123	2.170	3.548
	(0.041)	(0.083)	(0.052)	(0.424)	(0.191)
Japan	1.050	0.727	0.702	0.787	0.739
	(0.923)	(0.582)	(0.597)	(0.754)	(0.673)
Other countries	3.347	2.729	1.368	0.161	1.144
	(0.107)	(0.210)	(0.736)	(0.127)	(0.896)
Sector:					
Automotive	0.081	0.061	0.205	0.104	0.218
	(0.009)	(0.014)	(0.148)	(0.051)	(0.150)
Capital Goods	0.222	0.166	0.142	0.039	0.041
	(0.019)	(0.026)	(0.027)	(<.001)	(<.001)
Materials	0.103	0.088	0.060	0.012	0.006
	(0.001)	(0.005)	(0.005)	(<.001)	(<.001)
Technology	0.481	0.469	0.475	0.168	0.401
	(0.302)	(0.378)	(0.443)	(0.066)	(0.291)

Note: Multinomial logistic regression, exponentiated coefficients (Odds Ratio). Strategy (0) "No CE action" is the base level. Pseudo-R^2 (Nagelkerke) = 0.202. Total observations: 4288. Likelihood ratio test χ^2 (126 d.f.) = 959.65 (p-value <0.001). One-year lag for independent and control variables is used. *DJSI return* and *analyst coverage* are standardized. P.A. is Paris Agreement. Financial control variables are winsorized (1% level) and standardized. Standard errors clustered at the firm level (not reported). p-values in parentheses below odds ratios. All variables are defined in the appendix. All strategies are defined in Table 4 and Section 3.3.

Table 8, instead, show that the coefficients on the other CG mechanisms (i.e., *CSR committee, UNGC signatory,* and *ESG executive performance*) are not significant for all strategies.

Taken as a whole, results from Table 8 suggest that *stakeholder engagement, environment management teams,* and *sustainability reporting* can effectively push managers to reorient production processes, ultimately leading to the adoption of CE strategies. These results add up to the literature showing that environmental performance and strategies are supported by *sustainability reporting* (Córdova et al., 2018; Massa et al., 2015), *environment management team* (Dangelico, 2015; Jabbour et al., 2013) and *stakeholder engagement* (Dögl and Behnam, 2015; Jang et al., 2017; Papagiannakis et al., 2019). Our findings contribute to the extant literature by showing that these mechanisms not only support the adoption of environmental strategies in a broad sense but also foster the adoption of more and more complex strategies that imply an increasing commitment towards the circularization of the economy.

Results from Table 8 show that the coefficients on *stakeholder engagement* are substantially higher than those of other CG mechanisms in all Strategies, greatly increasing the likelihood that CE actions are implemented compared to no action. At the same time, results show that coefficients on *sustainability reporting* are substantially higher than on *environment management team* in Strategies (1), (2), and (4) and comparable in Strategies (3) and (5). These findings can be interpreted as *sustainability reporting* playing a more substantive role in promoting resource efficiency actions and take-back policies, while an *environment management team* is more important for the design of products that could be recycled, repaired, or refurbished at the end of their life cycle.

In contrast, the non-significant coefficients on *CSR committee, UNGC signatory,* and *ESG-related executives' performance* suggest that those elements do not represent a direct driver for the implementation of CE strategies. In the next section, we investigate whether these latter mechanisms really are uninfluential or if they may have an indirect effect on CE strategies.

The results for control variables indicate that other factors included in our model also play a role in promoting different strategies. Concerning external pressures, all the coefficients on the *Paris Agreement* variable in Table 8 are larger than 3 and with *p*-values lower or equal to 0.002, confirming our descriptive analysis showing increasing trends in more complex CE strategies after 2015. This result is in line with prior literature showing that such an event triggered the firms' commitment towards fighting climate change (Palea and Drogo, 2020) and with the notion that CE is a viable paradigm for achieving the Paris Agreement goals (UNFCCC, 2021). Coefficients for *DJSI return* are statistically significant only after the Paris Agreement, with coefficients larger than 3 and p-values lower or equal 0.05 for all strategies except (1). This result is in line with prior literatures showing that sustainable strategies and investment at the firm level have been influenced by sustainability-oriented stock market trends (Iqbal et al., 2022), particularly after increased awareness on environmental issues such as the Paris Agreement. Interestingly, coefficients on *analyst coverage* are statistically not significant in all strategies. This may be due to the fact that most of the companies covered by analysts are also the largest in size – variable for which we control as well. Coefficients on *GHG intensity* in Table 8 are larger than 1.8 and statistically significant (*p*-values at least lower than or equal 0.015), showing that more polluting firms have higher odds of implementing any CE strategy compared to none. This finding is consistent with prior studies showing that higher pollution causes higher stakeholder pressure on firms to reduce their carbon footprint (Cadez et al., 2019). Furthermore, our findings highlight that larger firm size and higher profitability increase the likelihood that firms adopt more complex CE strategies, while debt *leverage* has a negative impact in Strategies (4) and (5), albeit with *p*-values larger than 0.01. These findings are directly in line with the body of literature showing that firms committed towards sustainability practices are overall larger and more profitable (Migliavacca, 2023) and that they should be more financially robust to sustain the CE transition (Biondi et al., 2023).

When controlling for regional differences, results suggest that there are no differences among countries in sustaining CE strategies. However, these findings should be interpreted jointly with results for the Paris Agreement variable, which suggest that countries' commitment to fighting climate change has been effective in pushing firms to reorient their business model according to CE criteria. Finally, results indicate that firms in the Consumer Durables (base) sector are overall more likely to implement efficiency strategies compared to other industries. Interestingly, Durables, Technology, and Automotive industries have a higher likelihood of adopting Strategy (5) compared to Capital Goods and Materials. In fact, firms operating in these sectors usually sell their goods to final consumers, who can contribute to "closing the loop" by recycling, reusing, prolonging the life of products, or returning end-of-life goods to producers (Stahel, 2019). These firms, therefore, could have a higher stake in implementing more advanced circular economy strategies (Pieroni et al., 2021).

5.2. Additional analysis

The results from Table 8 suggest that the *CSR committee, UNGC signatory*, and *ESG executive compensation* have no direct impact on the likelihood of firms adopting CE strategies. In this respect, our findings are in contrast with other studies showing that these mechanisms have a positive impact on environmental performance (Flammer et al., 2019; Orazalin and Mahmood, 2021; Ortas et al., 2015). We, therefore, provide further analysis, investigating whether such CG mechanisms may exert an indirect impact on CE strategies by promoting either *stakeholder engagement, environment management teams,* or *sustainability reporting.* For instance, some studies suggest that the CSR committee could favour GHG disclosure (Córdova et al., 2018; Tingbani et al., 2020), which is usually included in sustainability reports. To test the presence of indirect effects, we perform a logistic regression as follows:

$$\begin{aligned}\log\frac{P(y_{i,t}=1)}{P(y_{i,t}=0)} &= \beta_0+\beta_1 CSR\ committee_{i,t-1}+\beta_2 UNGC\ signatory_{i,t-1}\\ &+\beta_2 ESG\ compensation_{i,t-1}+\beta_4 ParisAgreement_t\\ &+\beta_5 DJSIreturn_{t-1}+\beta_6 ParisAgreement_t\times DJSIreturn_{t-1}\\ &+\beta_7 AnalystCoverage_{i,t-1}++\beta_8 GHG\ intensity_{i,t-1}\\ &+\sum\nolimits_{n=9}^{11}\beta_n financial\ controls_{i,t-1}+\beta_{12} region_i+\beta_{13} sector_i\\ &+\varepsilon_{i,t}\end{aligned} \tag{2}$$

y is either *stakeholder engagement, environment management team,* or *sustainability reporting* of firm *i* at time *t*, and takes the value of 1 when the firm adopts it, zero otherwise. *CSR committee*, *UNGC signatory*, and *ESG executive compensation* are dummy variables that take the value of one when the firm *i* adopted the mechanism at time $t-1$, zero otherwise. We adopt the first lag of each independent variable to set the direction of the correlation. The other control variables are the same as in Equation (1). Table 9 reports the results (odds ratios) from the logistic regressions (Equation (2)).

Results from Table 9 indeed suggest an indirect effect of the *CSR committee, UNGC signatory,* and *ESG executive compensation* on the adoption of CE strategies. As displayed in Column 1, the *CSR committee* and *UNGC signatory* positively impact the adoption of *sustainability reporting* (coefficients 3.010, *p*-value<0.001, and 3.346, *p*-value = 0.004, respectively). *ESG executive compensation* has a coefficient greater than one with a large *p*-value (coefficient 1.232, *p*-value 0.480). Column 2, similarly, shows that firms are more likely to implement *stakeholder engagement* when they have *CSR Committee* and *UNGC signatory* (coefficients 3.796 and 2.408, respectively, *p*-values<0.001), while *ESG executive compensation* has a large *p*-value. Lastly, Column 3 shows that the *environment management team* is promoted mainly by the *CSR committee* (coefficient 2.693, *p*-value<0.001) and *ESG executive compensation* (coefficient 1.801, *p*-value 0.006), while the *UNGC signatory* has a *p*-value larger than 0.1.

From an organizational perspective, our findings suggest that *CSR committee, UNGC signatory* and *ESG executive compensation* may be preliminary CG mechanisms that firms adopt to signal their environmental standpoint and commitment towards the transition (Birindelli and Palea, 2022). Findings from our main model, in fact, highlight that these mechanisms have no direct impact on the implementation of efficiency

Table 9
Results from additional analyses.

Dependent variable	Sustainabilityr eporting	Stakeholder engagement	Environment management team
	(1)	(2)	(3)
Independent variables			
CSR committee	3.010	3.796	2.693
	(<.001)	(<.001)	(<.001)
ESG executive compensation	1.232	1.337	1.801
	(0.480)	(0.115)	(0.006)
UNGC signatory	3.346	2.408	1.105
	(0.004)	(<.001)	(0.631)
Control variables	Yes	Yes	Yes
Region	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Observations	4288	4288	4288
Pseudo-R^2	0.286	0.240	0.080
χ^2 (18 d.f.)	190.63	229.06	64.40
p-value	<0.001	<0.001	<0.001

Note: Logistic regression, exponentiated coefficients (Odds Ratio). One-year lag for independent variables is used. Continuous control variables are winsorized (1% level) and standardized. Standard errors clustered at the firm level (not reported). *p*-values in parentheses below odds ratios. Control variables include DJS Index Return, Analyst Coverage, Paris Agreement, GHG Intensity, Size, Profitability, and Leverage. All variables are defined in the appendix.

or closing loop actions. However, our additional analysis suggests that these governance mechanisms can promote the adoption of *stakeholder engagement*, *sustainability reporting*, or *environment management teams,* thus playing an indirect but significant role in the adoption of CE strategies.

Interestingly, results for control variables (untabulated for the sake of brevity and readability) show that external pressures also stimulate the adoption of CG mechanisms, along with their direct effects on the adoption of CE strategies. For instance, the *Paris Agreement* mainly stimulated *stakeholder engagement*, while the *DJSI return* positively stimulated *sustainability reporting*, and *environmental management teams* after the Paris Agreement. Our additional model also suggests that *size* exerts a positive impact on CG mechanisms, while *GHG intensity* and *profitability* mainly have a secondary role in promoting *sustainability reporting*. Finally, the *region* control shows that being a firm operating in Europe increases the likelihood of implementing *stakeholder engagement* and *sustainability reporting* practices compared to all other regions, in line with the increasing sustainability regulations that those firms face (e.g., European Commission, 2023, 2022, 2020b, 2020a, 2019, 2018, 2015).

6. Concluding remarks

The transition towards a circular economy can profoundly improve society's well-being by yielding environmental, social, and economic benefits. Non-financial corporations, particularly industrial ones, are key in scaling up the transition towards sustainable development by adopting circular economy paradigms. This paper analyses the corporate governance drivers of CE strategies in manufacturing listed companies, showing that *stakeholder engagement*, *sustainability reporting*, and *environment management teams* play an important role in supporting the adoption of CE strategies. In contrast, the presence of a board-level *CSR committee*, the adhesion to the *UNGC principles*, and contracting executives' *compensation* based on ESG performance have no direct impact on the likelihood that firms implement CE strategies. However, additional analyses suggest that these governance mechanisms play an indirect role in promoting CE strategies by fostering *sustainability reporting*, *stakeholder engagement*, and *environment management teams*.

Our results can be of interest to managers, investors, and policymakers. From a managerial point of view, research has proved that implementing CE strategies has a positive impact on the financial performance of firms (Palea et al., 2023). Our findings well complement this literature by shedding light on which internal CG mechanisms can be put in place inside organizations to support the adoption of CE strategies. This paper, therefore, can also be of interest to investors, which should consider CE strategies in shaping forward-looking, rather than point-in-time, asset allocation strategies focusing on sustainable activities, as highlighted by the literature on sustainable finance (Moneva et al., 2023; Sepetis, 2022). Lastly, from a policymaker's perspective, our results provide empirical evidence for lawmaking in the field of corporate governance. For instance, the proposed EU Corporate Sustainability Due Diligence Directive promotes the adoption of sustainable governance practices to strengthen human rights and environmental due diligence (EC, 2023). In this respect, our findings provide helpful information for defining effective pathways towards firms' circularity that leverage CG mechanisms.

Our analysis is not free from limitations, which could serve as a useful starting point for future research. First of all, we relied on binary indicators drawn from the Refinitiv database, which do not capture to what extent, timeframe, or long-term orientation companies adopt different CE actions. As more detailed data on CE practices become available, research will be able to improve the accuracy of CE measurements at the firm level (e.g. in Europe, as an effect of the EU's Corporate Sustainability Reporting Directive and Sustainable Activities and Social Taxonomies). Furthermore, the Refinitiv database contains ESG information for listed companies only, which, however, represent a minority of companies worldwide. In fact, small and medium-sized enterprises (SMEs) represent 99% of the companies, which employ more than 70% of the workforce and contribute to more than 50% of GDP in high-income countries (McKinsey, 2022; OECD, 2017). Accordingly, further research could well complement our study by creating a new database for SMEs, which allows for investigating the adoption and diffusion of circular practices in smaller entities. This would also make it possible to compare listed and non-listed companies on CE behaviors. For instance, SMEs are often family-owned and could therefore put in place different CG mechanisms compared to listed companies (Brunninge et al., 2007). Geographical areas and sectors could also be refined to get further insights into how national legislations and ecosystems can lead to the adoption of different CG mechanisms and CE strategies in different industries. For instance, CE could be particularly relevant and promising in agriculture industry (United Nations Industrial Development Organization, 2020), as it is considered one of the highest emitting (European Commission, 2022) and one of the most exposed to transition and physical risks (European Central Bank, 2020).

CRediT authorship contribution statement

Vera Palea: Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision. **Alessandro Migliavacca:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Silvia Gordano:** Writing – original draft, Data curation, Visualization.

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

The authors do not have permission to share data.

Appendix

Table A0.1
Variables

Variable label	Refinitiv datatype code	Description
Energy efficiency	ENRRDP0122	'Does the company have a policy to improve its energy efficiency?'
Water efficiency	ENRRDP0121	'Does the company have a policy to improve its water efficiency?'
Renewable energy use	ENRRDP046	'Does the company make use of renewable energy?'
Waste reduction	ENERDP062	'Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out any type of waste?'

(*continued on next page*)

Table A0.1 (*continued*)

Variable label	Refinitiv datatype code	Description
Product eco-design	ENPIDP069	'Does the company report on specific products which are designed for reuse, recycling or the reduction of environmental impacts?'
Take-back initiatives	ENPIDP047	'Does the company report about take-back procedures and recycling programs to reduce the potential risks of products entering the environment?'
Bord-level CSR Committee	CGVSDP005	'Does the company have a CSR committee or team?'
Environment management team	ENRRDP004	'Does the company have an environment management team?'
UNGC signatory status	CGVSDP020	'Has the company signed the UNGC?'
ESG executive compensation	CGCPDP0013	'Does the company have an extra-financial performance-oriented compensation policy?'
Stakeholder engagement	CGVSDP023	'Does the company explain how it engages with its stakeholders?'
Sustainability reporting	CGVSDP026	'Does the company publish a separate CSR/Sustainability report or publish a section in its annual report on CSR/Sustainability?'
Size	WC02999	Log (total assets)
Profitability	WC01250/WC01151	Operating income before depreciation/total assets
Leverage	WC03255	Total debt/Total assets
GHG intensity	ENERDPO23	Total CO_2 equivalent emissions/total revenues
Analyst coverage	TR.NumberOfAnalysts	RDP Equities Data
Dow Jones Sustainability Index Return (DJS Index Return)	(DJSWDC$) NR	Datastream Equity Index data – Net Return
Region	CODOC	Are the world regions from which sample is extracted
Sector	GDSCN	Are the GICS sectors from which sample is extracted

References

Aguilar-Hernandez, G.A., Rodrigues, J.F.D., Tukker, A., 2021. Macroeconomic, social and environmental impacts of a circular economy up to 2050: a meta-analysis of prospective studies. J. Clean. Prod. 278, 123421 https://doi.org/10.1016/j.jclepro.2020.123421.

Aguinis, H., Glavas, A., 2012. What we know and don't know about corporate social responsibility: a review and research agenda. J. Manag. 38, 932–968. https://doi.org/10.1177/0149206311436079.

Aswani, J., Raghunandan, A., Rajgopal, S., 2023. Are carbon emissions associated with stock returns? Review of Finance. https://doi.org/10.2139/ssrn.3800193.

Baraibar-Diez, E., Odriozola, M.D., Fernández Sánchez, J.L., 2019. Sustainable compensation policies and its effect on environmental, social, and governance scores. Corp. Soc. Responsib. Environ. Manag. 1457–1472. https://doi.org/10.1002/csr.1760.

Barkemeyer, R., Comyns, B., Figge, F., Napolitano, G., 2014. CEO statements in sustainability reports: substantive information or background noise? Account. Forum 38, 241–257. https://doi.org/10.1016/j.accfor.2014.07.002.

Barros, V., Verga Matos, P., Miranda Sarmento, J., Rino Vieira, P., 2022. M&A activity as a driver for better ESG performance. Technol. Forecast. Soc. Change 175, 121338. https://doi.org/10.1016/j.techfore.2021.121338.

Berliner, D., Prakash, A., 2015. "Bluewashing" the firm? Voluntary regulations, program design, and member compliance with the United Nations' Global Compact. Pol. Stud. J. 43, 115–138.

Biondi, Y., Haslam, C., Malberti, C., 2023. ELI Guidance on Company Capital and Financial Accounting for Corporate Sustainability (No. P-2021-26). European Law Institute.

Birindelli, G., Palea, V., 2022. To green or not to green? How CSR mechanisms at the governance level affect the likelihood of banks pursuing green product strategies. Corp. Govern.: Int. J. Bus. Soc. https://doi.org/10.1108/CG-09-2021-0349.

Blasi, S., Crisafulli, B., Sedita, S.R., 2021. Selling circularity: understanding the relationship between circularity promotion and the performance of manufacturing SMEs in Italy. J. Clean. Prod. 303, 127035 https://doi.org/10.1016/j.jclepro.2021.127035.

Bocken, N.M.P., de Pauw, I., Bakker, C., van der Grinten, B., 2016. Product design and business model strategies for a circular economy. J. Ind. Production Eng. 33, 308–320. https://doi.org/10.1080/21681015.2016.1172124.

Brauer, M., Wiersema, M., 2018. Analyzing analyst research: a review of past coverage and recommendations for future research. J. Manag. 44, 218–248. https://doi.org/10.1177/0149206317734900.

Brunninge, O., Nordqvist, M., Wiklund, J., 2007. Corporate governance and strategic change in SMEs: the effects of ownership, board composition and top management teams. Small Bus. Econ. 29, 295–308. https://doi.org/10.1007/s11187-006-9021-2.

Cadez, S., Czerny, A., Letmathe, P., 2019. Stakeholder pressures and corporate climate change mitigation strategies. Bus. Strat. Environ. 28, 1–14. https://doi.org/10.1002/bse.2070.

Cainelli, G., D'Amato, A., Mazzanti, M., 2020. Resource efficient eco-innovations for a circular economy: evidence from EU firms. Res. Pol. 49, 103827 https://doi.org/10.1016/j.respol.2019.103827.

Calzolari, T., Genovese, A., Brint, A., 2021. The adoption of circular economy practices in supply chains–An assessment of European Multi-National Enterprises. J. Clean. Prod. 312, 127616 https://doi.org/10.1016/j.jclepro.2021.127616.

Cattell, R.B., 1966. The scree test for the number of factors. Multivariate Behav. Res. 1, 245–276. https://doi.org/10.1207/s15327906mbr0102_10.

Centobelli, P., Cerchione, R., Esposito, E., Passaro, R., 2021. Determinants of the transition towards circular economy in SMEs: a sustainable supply chain management perspective. Int. J. Prod. Econ. 242, 108297 https://doi.org/10.1016/j.ijpe.2021.108297.

Cheffi, W., Zahir-ul-Hassan, M.K., Farooq, M.O., Baqrain, A., Mansour, M.M.H., 2023. Ethical leadership, management control systems and circular economy in SMEs in an emerging economy, the UAE. J. Bus. Res. 156, 113513 https://doi.org/10.1016/j.jbusres.2022.113513.

Córdova, C., Zorio-Grima, A., Merello, P., 2018. Carbon emissions by South American companies: driving factors for reporting decisions and emissions reduction. Sustainability 10, 2411. https://doi.org/10.3390/su10072411.

Cowen, S.S., Ferreri, L.B., Parker, L.D., 1987. The impact of corporate characteristics on social responsibility disclosure: a typology and frequency-based analysis. Account. Org. Soc. 12, 111–122. https://doi.org/10.1016/0361-3682(87)90001-8.

Dangelico, R.M., 2015. Improving firm environmental performance and reputation: the role of employee green teams. Bus. Strat. Environ. 24, 735–749. https://doi.org/10.1002/bse.1842.

de Villiers, C., La Torre, M., Molinari, M., 2022. The Global Reporting Initiative's (GRI) past, present and future: critical reflections and a research agenda on sustainability reporting (standard-setting). Pac. Account. Rev. 34, 728–747. https://doi.org/10.1108/PAR-02-2022-0034.

Demirel, P., Danisman, G.O., 2019. Eco-innovation and firm growth in the circular economy: evidence from European small-and medium-sized enterprises. Bus. Strat. Environ. 28, 1608–1618. https://doi.org/10.1002/bse.2336.

Dimaggio, P., Powell, W.W., 1983. The iron cage revisited institutional isomorphism and collective rationality in organizational fields. Am. Socio. Rev. 48, 143–166. https://doi.org/10.1016/s0742-3322(00)17011-1.

Dögl, C., Behnam, M., 2015. Environmentally sustainable development through stakeholder engagement in developed and emerging countries. Bus. Strat. Environ. 24, 583–600. https://doi.org/10.1002/bse.1839.

Ellen MacArthur Foundation, 2013. Towards the Circular Economy Vol. 1: an Economic and Business Rationale for an Accelerated Transition. https://ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an.

Esposito, M., Tse, T., Soufani, K., 2018. Introducing a circular economy: new thinking with new managerial and policy implications. Calif. Manag. Rev. 60, 5–19. https://doi.org/10.1177/0008125618764691.

European Central Bank, 2020. Guide on Climate-Related and Environmental Risks. European Central Bank.

European Commission, 2023. Proposal for a Directive on Corporate Sustainability Due Diligence (CSDDD) (No. COM(2022) 71 Final.

European Commission, 2022. EC Delegated Regulation 2022/1288. EC Delegated Regulation supplementing Regulation (EU) 2019/2088.

European Commission, 2020a. A New Circular Economy Action Plan.

European Commission, 2020b. Regulation (EU) 2020/852 (Taxonomy for Sustainable Activities), OJ L.

European Commission, 2019. The European Green Deal (No. COM (2019) 640 Final.

European Commission, 2018. European Commission action plan: financing sustainable growth (No. COM(2018) 97 final. Author Brussels, Belgium.

European Commission, 2015. Closing the Loop. An EU Action Plan for the Circular Economy. No. COM(2015) 614 final).

Flammer, C., Hong, B., Minor, D., 2019. Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: effectiveness and implications for firm outcomes. Strat. Manag. J. 40, 1097–1122. https://doi.org/10.1002/smj.3018.

Freeman, R.E., 1984. Strategic Management: A Stakeholder Approach. Pitman Publishing Company, Boston, MA.
Frees, E.W., 2004. Longitudinal and Panel Data: Analysis and Applications in the Social Sciences. Cambridge University Press.
Genovese, A., Acquaye, A.A., Figueroa, A., Koh, S.L., 2017. Sustainable supply chain management and the transition towards a circular economy: evidence and some applications. Omega 66, 344–357. https://doi.org/10.1016/j.omega.2015.05.015.
Gusmerotti, N.M., Testa, F., Corsini, F., Pretner, G., Iraldo, F., 2019. Drivers and approaches to the circular economy in manufacturing firms. J. Clean. Prod. 230, 314–327. https://doi.org/10.1016/j.jclepro.2019.05.044.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2013. Multivariate Data Analysis. Pearson Education Limited.
Han, M., Lin, H., Sun, D., Wang, J., Yuan, J., 2022. The eco-friendly side of analyst coverage: the case of green innovation. IEEE Trans. Eng. Manag. 1–16. https://doi.org/10.1109/TEM.2022.3148136.
Haque, F., 2017. The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms. Br. Account. Rev. 49, 347–364. https://doi.org/10.1016/j.bar.2017.01.001.
Haque, F., Ntim, C.G., 2020. Executive compensation, sustainable compensation policy, carbon performance and market value. Br. J. Manag. 31, 525–546. https://doi.org/10.1111/1467-8551.12395.
Hart, S.L., 1995. A natural-resource-based view of the firm. AMR (Adv. Magn. Reson.) 20, 986–1014. https://doi.org/10.5465/amr.1995.9512280033.
Hawn, O., Chatterji, A.K., Mitchell, W., 2018. Do investors actually value sustainability? New evidence from investor reactions to the Dow Jones Sustainability Index (DJSI). Strat. Manag. J. 39, 949–976. https://doi.org/10.1002/smj.2752.
Hsueh, L., 2017. Transnational climate governance and the Global 500: examining private actor participation by firm-level factors and dynamics. Int. Interact. 43, 48–75. https://doi.org/10.1080/03050629.2016.1223929.
Iqbal, N., Naeem, M.A., Suleman, M.T., 2022. Quantifying the asymmetric spillovers in sustainable investments. J. Int. Financ. Mark. Inst. Money 77, 101480. https://doi.org/10.1016/j.intfin.2021.101480.
Jabbour, C.J.C., Santos, F.C.A., Fonseca, S.A., Nagano, M.S., 2013. Green teams: understanding their roles in the environmental management of companies located in Brazil. J. Cleaner Production, Key Elements (Stages and Tools) for a Sus. World 46, 58–66. https://doi.org/10.1016/j.jclepro.2012.09.018.
Jang, Y.J., Zheng, T., Bosselman, R., 2017. Top managers' environmental values, leadership, and stakeholder engagement in promoting environmental sustainability in the restaurant industry. Int. J. Hospit. Manag. 63, 101–111. https://doi.org/10.1016/j.ijhm.2017.03.005.
Jastram, S.M., Klingenberg, J., 2018. Assessing the outcome effectiveness of multi-stakeholder initiatives in the field of corporate social responsibility–The example of the United Nations Global Compact. J. Clean. Prod. 189, 775–784. https://doi.org/10.1016/j.jclepro.2018.04.005.
Kiefer, C.P., Del Río González, P., Carrillo-Hermosilla, J., 2019. Drivers and barriers of eco-innovation types for sustainable transitions: a quantitative perspective. Bus. Strat. Environ. 28, 155–172. https://doi.org/10.1002/bse.2246.
Ludwig, P., Sassen, R., 2022. Which internal corporate governance mechanisms drive corporate sustainability? J. Environ. Manag. 301, 113780 https://doi.org/10.1016/j.jenvman.2021.113780.
Massa, L., Farneti, F., Scappini, B., 2015. Developing a sustainability report in a small to medium enterprise: process and consequences. Meditari Account. Res. 23, 62–91. https://doi.org/10.1108/MEDAR-02-2014-0030.
McKinsey, 2022. Helping Small and Medium-Size Enterprises Thrive. https://www.mckinsey.com/industries/public-sector/our-insights/beyond-financials-helping-small-and-medium-size-enterprises-thrive#/.
Meyer, J.W., Rowan, B., 1977. Institutionalized organizations: Formal structure as myth and ceremony. Am. J. Sociol. 83, 340–363.
Migliavacca, A., 2023. Value relevance of accounting numbers and sustainability information in Europe: empirical evidence from nonfinancial companies. J. Int. Account. Audit. Taxat.(Forthcoming) - available on https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4498581.
Moneva, J.M., Scarpellini, S., Aranda-Usón, A., Alvarez Etxeberria, I., 2023. Sustainability reporting in view of the European sustainable finance taxonomy: is the financial sector ready to disclose circular economy? Corp. Soc. Responsib. Environ. Manag. 30, 1336–1347. https://doi.org/10.1002/csr.2423.
Nobre, G.C., Tavares, E., 2021. The quest for a circular economy final definition: a scientific perspective. J. Clean. Prod. 314, 127973 https://doi.org/10.1016/j.jclepro.2021.127973.
OECD, 2017. Enhancing the contributions of SMES in a global and digitalised economy. In: Meeting of the OECD Council at Ministerial Level. OECD, Paris.
Orazalin, N., Mahmood, M., 2021. Toward sustainable development: board characteristics, country governance quality, and environmental performance. Bus. Strat. Environ. 30, 3569–3588. https://doi.org/10.1002/bse.2820.
Ortas, E., Álvarez, I., Garayar, A., 2015. The environmental, social, governance, and financial performance effects on companies that adopt the United Nations Global Compact. Sustainability 7, 1932–1956. https://doi.org/10.3390/su7021932.
Oyewo, B., 2023. Corporate governance and carbon emissions performance: international evidence on curvilinear relationships. J. Environ. Manag. 334, 117474 https://doi.org/10.1016/j.jenvman.2023.117474.
Palea, V., Drogo, F., 2020. Carbon emissions and the cost of debt in the eurozone: the role of public policies, climate-related disclosure and corporate governance. Bus. Strat. Environ. 29, 2953–2972. https://doi.org/10.1002/bse.2550.
Palea, V., Santhià, C., Miazza, A., 2023. Are circular economy strategies economically successful? Evidence from a longitudinal panel. J. Environ. Manag. 337, 117726 https://doi.org/10.1016/j.jenvman.2023.117726.
Papagiannakis, G., Voudouris, I., Lioukas, S., Kassinis, G., 2019. Environmental management systems and environmental product innovation: the role of stakeholder engagement. Bus. Strat. Environ. 28, 939–950. https://doi.org/10.1002/bse.2293.
Petersen, M.A., 2009. Estimating standard errors in finance panel data sets: comparing approaches. Rev. Financ. Stud. 22, 435–480. https://doi.org/10.1093/rfs/hhn053.
Pfeffer, J., Salancik, G.R., 1978. The External Control of Organizations: A Resource Dependence Perspective. Stanford University Press.
Pieroni, M.P., McAloone, T.C., Pigosso, D.C., 2021. Circular economy business model innovation: sectorial patterns within manufacturing companies. J. Clean. Prod. 286, 124921 https://doi.org/10.1016/j.jclepro.2020.124921.
Plaza-Úbeda, J.A., de Burgos-Jiménez, J., Carmona-Moreno, E., 2010. Measuring stakeholder integration: knowledge, interaction and adaptational behavior dimensions. J. Bus. Ethics 93, 419–442. https://doi.org/10.1007/s10551-009-0231-9.
Refinitiv, 2023 [WWW Document]. URL Financial Data Catalogue. https://www.refinitiv.com/en/financial-data.
Rodrigue, M., Magnan, M., Cho, C.H., 2013. Is environmental governance substantive or symbolic? An empirical investigation. J. Bus. Ethics 114, 107–129. https://doi.org/10.1007/s10551-012-1331-5.
Romero, S., Ruiz, S., Fernandez-Feijoo, B., 2019. Sustainability reporting and stakeholder engagement in Spain: different instruments, different quality. Bus. Strat. Environ. 28, 221–232. https://doi.org/10.1002/bse.2251.
Ruiz, S., Romero, S., Fernandez-Feijoo, B., 2021. Stakeholder engagement is evolving: do investors play a main role? Bus. Strat. Environ. 30, 1105–1120. https://doi.org/10.1002/bse.2674.
Saeed, A., Noreen, U., Azam, A., Tahir, M.S., 2021. Does CSR governance improve social sustainability and reduce the carbon footprint: international evidence from the energy sector. Sustainability 13, 3596. https://doi.org/10.3390/su13073596.
Salem, M.A., Shawtari, F., Shamsudin, M.F., Hussain, H.B.I., 2017. The consequences of integrating stakeholder engagement in sustainable development (environmental perspectives). Sustain. Dev. 26, 255–268. https://doi.org/10.1002/sd.1699.
Schmidt, C.V.H., Kindermann, B., Behlau, C.F., Flatten, T.C., 2021. Understanding the effect of market orientation on circular economy practices: the mediating role of closed-loop orientation in German SMEs. Bus. Strat. Environ. 30, 4171–4187. https://doi.org/10.1002/bse.2863.
Searcy, C., 2012. Corporate sustainability performance measurement systems: a review and research agenda. J. Bus. Ethics 107, 239–253. https://doi.org/10.1007/s10551-011-1038-z.
Sepetis, A., 2022. Chapter 13 - sustainable finance and circular economy. In: Stefanakis, A., Nikolaou, I. (Eds.), Circular Economy and Sustainability. Elsevier, pp. 207–226. https://doi.org/10.1016/B978-0-12-819817-9.00002-8.
Siedschlag, I., Meneto, S., Tong Koecklin, M., 2022. Enabling green innovations for the circular economy: what factors matter? Sustainability 14, 12314. https://doi.org/10.3390/su141912314.
Stahel, W.R., 2019. The Circular Economy: A User's Guide. Routledge.
Tang, S., Higgins, C., 2022. Do not forget the "How" along with the "What": improving the transparency of sustainability reports. Calif. Manag. Rev. 65, 44–63. https://doi.org/10.1177/00081256221094876.
Tingbani, I., Chithambo, L., Tauringana, V., Papanikolaou, N., 2020. Board gender diversity, environmental committee and greenhouse gas voluntary disclosures. Bus. Strat. Environ. 29, 2194–2210. https://doi.org/10.1002/bse.2495.
Triguero, Á., Cuerva, M.C., Sáez-Martínez, F.J., 2022. Closing the loop through eco-innovation by European firms: circular economy for sustainable development. Bus. Strat. Environ. 31, 2337–2350. https://doi.org/10.1002/bse.3024.
United Nations, 2021. United Nations framework convention on climate change (UNFCCC): shifting to a circular economy essential to achieving. Paris Agreement Goals. https://unfccc.int/news/shifting-to-a-circular-economy-essential-to-achieving-paris-agreement-goals.
United Nations Industrial Development Organization, 2020. Circular Economy and Agribusiness Development.
United States Environmental Protection Agency (EPA), 2022. What is a Circular Econ.? https://www.epa.gov/circulareconomy/what-circular-economy.
Urbinati, A., Chiaroni, D., Chiesa, V., 2017. Towards a new taxonomy of circular economy business models. J. Clean. Prod. 168, 487–498. https://doi.org/10.1016/j.jclepro.2017.09.047.
Vachon, S., Klassen, R.D., 2008. Environmental management and manufacturing performance: The role of collaboration in the supply chain. International journal of production economics 111 (2), 299–315.
Van Berkel, R., Fadeeva, Z., 2020. Role of industries in resource efficiency and circular economy. In: Ghosh, S.K. (Ed.), Waste Management as Economic Industry towards Circular Economy. Springer, Singapore, pp. 171–183. https://doi.org/10.1007/978-981-15-1620-7_20.
Van Opstal, W., Borms, L., 2023. Startups and circular economy strategies: profile differences, barriers and enablers. J. Clean. Prod. 396, 136510 https://doi.org/10.1016/j.jclepro.2023.136510.
Wernerfelt, B., 1984. A resource-based view of the firm. Strat. Manag. J. 5, 171–180. https://doi.org/10.1002/smj.4250050207.
World Economic Forum, 2019. Making the $4.5 Trillion Circular Economy Opportunity a Reality. https://www.weforum.org/impact/helping-the-circular-economy-become-a-reality/.
Zhang, Q., Oo, B.L., Lim, B.T.H., 2019. Drivers, motivations, and barriers to the implementation of corporate social responsibility practices by construction enterprises A review. J. Clean. Prod. 210, 563–584. https://doi.org/10.1016/j.jclepro.2018.11.050.