Environment, Development and Sustainability
https://doi.org/10.1007/s10668-024-04817-w

Seeing through the haze: greenwashing and the cost of capital in technology firms

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Received: 29 November 2023 / Accepted: 17 March 2024

Abstract

This paper investigates the financial impact of corporate sustainability greenwashing in the global Technology sector. Using environmental, social and governance (ESG) controversy data spanning between 2014 and 2021, we examine how media-reported conflicts linking companies to dubious sustainability claims influence financing costs. Models estimate effects on weighted average cost of capital, cost of equity, and cost of debt, contrasting overall controversies around issues against strictly environmental cases. Further analysis discriminates between high and low systematic risk technology firms. Results reveal increased overall sustainability controversies are associated with lower equity financing expenses, indicating investors continue value growth prospects despite ethical concerns. However, strict environmental controversies increase all financing costs. Findings suggest visibility of environmental externalities is sufficiently tangible that greenwashing them backfires financially, unlike shadowy social conduct. Additionally, lower systematic risk firms suffer harsher greenwashing penalties, implying resilience to disruption reduces misleading incentives. Transparency is currently inadequate immunisation against greenwashing in the Technology sector, necessitating oversight reforms. Stricter auditing and disclosure requirements would enable investors to accurately price sustainability risk and channel funds toward authentic sustainability transformation. Moreover, Technology companies must credibly convey environmental progress to avoid value destruction from questionable claims. Accordingly, managers should proactively invest in sustainability to mitigate reputation risks and access financing at lower costs. Ultimately, multifaceted transparency and coordinated policy responses are essential to realize genuine sustainability in disruptive, high-impact technologies.

Keywords Greenwashing · Cost of capital · Technology · ESG controversies · Dynamic panel modelling

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Published online: 05 April 2024

1 Introduction

Undoubtedly one of the greatest investment trends of the twenty-first century in investing is related to sustainability, or, considering its operationalization, to ESG—Environment, Social & Governance—factors, that affect investment decisions of institutions and population alike. According to Morningstar, as much as 40% of newly invested money in the asset management world are targeted to ESG conscious funds. Sustainability is transforming financial markets as investors increasingly incorporate ESG factors into capital allocation decisions amidst growing societal pressures for responsibility (Busch et al., 2016). Amid the new fashion however, more and more news are targeted to companies and investment funds that purposefully embellish their environment impact reports ad even social impact or governance indicators in a "window-dressing" competition for the world's largest liquidity pools. The most recent global greenwashing report by RepRisk (2023) shows an alarming rise of greenwashing practices across various industries and regions. The data collected by RepRisk indicates an increase of climate-related ESG risk occurrences from one in five in 2022 to one in four in 2023, mostly accelerated in North America and Europe. The Oil and Gas, Banking and Financial Services, and Utilities are the most exposed sectors to greenwashing. Moreover, the Banking and Financial Services sector recorded a 70% increase in the number of climate-related greenwashing incidents between 2022 and 2023, compared to the previous 1-year period. Additionally, nearly one in three public companies linked to greenwashing were associated with social washing, which takes place when companies paint themselves in a positive light by obscuring an underlying social issue to safeguard reputation and financial performance. According to PriceWaterhouseCoopers (2022), almost 90% of investors think that corporate reporting on sustainability contains greenwashing, and around 80% of analysed companies say their clients demand that ESG factors to be considered. This is proof of scepticism lingering over corporate commitments as superficial "greenwashing" to attract financing, without genuine change in conduct (Yang et al., 2020). These underscore the need for greater transparency, accountability, and regulatory oversight to combat this deceptive corporate behaviour.

That ESG claims attract conscious investors is clear, but what is the relationship between ESG practices and financial performance? That is less clear. Can companies attract more money and invest them in profitable, environment-friendly projects? A study by New York University Stern Center for Sustainable Business conducted in 2021 found that, in almost 60% of the cases studied, there was a positive link between ESG criteria and financial performance as evaluated by Return on Assets or Return on Equity (Whelan et al., 2021). However, the impact of organizations' sustainable plans, activities, and practices on corporate financial performance is still a developing topic of research. Scholarly inquiries into how firms utilize greenwashing to portray a better picture of sustainability concerns are also in their early stages.

Greenwashing first surfaced at the end of the 1990s and the beginning of the 2000s as a notion defined by three aspects of deception: confusion, fronting, and posturing (Laufer, 2003). Actually, the term "greenwashing" was invented by environmentalist Jay Westervelt in 1986, when he wrote an essay on the hospitality industry's methods to promote towel reuse (Wang et al., 2017).

The phrase "greenwashing" refers to the practice of businesses making false claims about the ecological compatibility or sustainability of their products and operations (Romero, 2008). Seele and Gatti (2017) attempt to develop a classification system for greenwashing in their study, depending on corporate legitimacy methods. Greenwashing behaviours include selective disclosure, decoupling of policies and practices, diverting attention away from bad behaviours, and the use of false environmental certifications or branding.

According to Lyon and Montgomery (2015), the term "greenwashing" encompasses a wider range of communication strategies that lead stakeholders to develop excessively positive perceptions regarding an organization's environmental performance, practices, or products. This definition encompasses both deliberate deceit as well as inadvertent amplification of sustainability attributes. For Cherry (2014), the absence of a universally agreed upon legal definition of greenwashing poses challenges in terms of its enforcement. The author suggests a precise delineation of greenwashing as the act of corporations providing consumers with misleading information regarding the environmental advantages associated with their products, services, or the corporation as a whole. Legal definitions typically prioritize the identification of advertising claims that are false or deceptive in relation to environmental advantages. Delmas and Burbano (2011) propose a comprehensive conceptual framework for greenwashing, which encompasses two dimensions: firms' environmental performance and their communication policies. The phenomenon of greenwashing arises when there is a discrepancy between an entity's unsatisfactory environmental practices and its promotion of positive messaging regarding its environmental performance. The disparity between verbal assertions and corresponding actions represents a fundamental attribute of greenwashing.

Considering existing research, the phenomenon of greenwashing is observed to be prevalent and exhibiting an upward trend. According to TerraChoice's (2009) research, there was a notable increase of 73% in the availability of environmentally-friendly products in North America between 2009 and 2010. This surge in green product offerings indicates a heightened level of interest in environmental marketing, which in turn raises concerns regarding the potential for greenwashing. In the study of Yojana (2021), it is estimated that a significant proportion of corporate environmental claims worldwide, over 40%, are misleading. This misleading information is responsible for the staggering amount of over $900 billion spent annually on products and services falsely marketed as environmentally friendly. The data presented suggests that greenwashing is widespread.

The technology sector has been one of the most dynamic sectors, particularly since the Covid-19 pandemic. Furthermore, because technology is always changing, there is greater uncertainty in performance and shorter business cycles. Also, because the Technology sector rarely employs highly polluting operations (e.g., oil extraction, construction material manufacture, etc.), it presents a more fruitful ground for research due to less contradiction between input and output. As a result, the Technology sector is highly interesting to our research. However, as technology becomes more pervasive in our daily lives, associated externalities such as e-waste accumulation, aggressive data collecting, and platform labour conditions come under investigation (Rim et al., 2005). With rapid innovation lifecycles, integrating sustainability and financial performance presents challenges between short-term profits and long-term business objectives, making technology firms good targets for greenwashing accusations (Seele & Schultz, 2022). However, research on the use of sustainability communications by Technology firms to manage financial performance and financing costs is sparse.

We investigate the influence of greenwashing on companies' cost of capital as a measure of business performance in the Technology sector. While various research has been conducted to examine the relationship between sustainability practices and cost of capital, there is limited knowledge regarding the influence of greenwashing on corporate financing costs. Furthermore, studies linking ESG and the weighted average cost of capital provide inconsistent data. As a result, we add this work to the body of literature on a topical topic while also discouraging dishonest reporting methods that may have a negative impact on a firm's cost of capital.

This paper makes three key contributions to this research field. First, it uses Refinitiv data on media-reported sustainability controversies to evaluate greenwashing links with Technology firms' equity, debt and weighted-average costs of capital from 2014 to 2021—one of the longest panels used in the literature to assess greenwashing's financial impacts. Second, the analysis discriminates between sustainability controversies overall and strictly environmental ones. Comparing dynamics for the composite ESG controversies measure against the environmental sub-component provides novel evidence of whether greenwashing impacts differ when strictly environmental greenwashing or overall greenwashing are considered. Third, comparing effects of greenwashing on cost of capital for high versus low systematic risk Technology firms will demonstrate if greenwashing penalization depends on business model resilience. Findings will compel investors to set capital costs aligned with authentic sustainability transformation, not superficial greenwashing.

Overall, our findings reveal whether transparency is sufficient to prevent greenwashing, or whether aggressive policy action is required to direct investments toward sustainability. With several research disagreeing on greenwashing's prevalence or significance (Bowen & Aragon-Correa, 2014; Delmas & Burbano, 2011; Wang et al., 2020), this paper's focus on the Technology sector provides much needed empirical evidence. The findings inform policymakers and industry executives who are attempting to reconcile short-term returns with long-term well-being when funding disruptive innovation.

The rest of the work is divided into four sections. The next section discusses the most important and relevant results of the existing literature and provides the basis for the empirical analysis. We also present the data and the research methodology. The panel data set used in the study is analysed in the next section using a dynamic panel GMM methodology, which also interprets the results and compares them with existing evidence in the literature. The final section of the paper concludes with an overview of the implications of our findings and suggestions for opportunities for future research, while acknowledging the limitations of the current endeavour.

2 Literature review

The existing scholarly literature on greenwashing exhibits a wide range of scope and methodological approaches. The phenomenon of greenwashing has been examined using several approaches, including conceptual analysis, consumer viewpoint analysis, content analysis, case studies, empirical methodologies, integration into corporate social responsibility literature, and policy analysis. In this section, we provide a concise overview and analysis of the findings from the literature. We also highlight the existing gaps that serve as the motivation behind our research.

Delmas and Burbano (2011) identified are two primary factors that motivate companies to engage in greenwashing practices. The first factor is the desire to establish legitimacy among stakeholders, as explained by institutional and legitimacy theories. The second factor involves the intention to communicate certain values to stakeholders through symbolic actions that are not necessarily backed by substantive environmental efforts. According to Roulet and Touboul (2015), companies that exhibit lower levels of environmental performance metrics are more likely to engage in greenwashing practices. This is driven by their desire to enhance their perceived legitimacy among consumers and investors, who are placing greater emphasis on sustainability considerations.

Lyon and Montgomery (2015) argue that the presence of ambiguity regarding the interpretations of sustainability contributes to the emergence and continuation of greenwashing practices, when viewed through the lens of institutional theory. The absence of universally agreed-upon definitions and standards pertaining to environmental concepts allows companies to exploit ambiguities, thereby enabling them to present deceptive or exaggerated assertions. At the same time, the impetus behind greenwashing is frequently rooted in the pursuit of financial gain (Du, 2015). Firms may intentionally engage in the dissemination of inaccurate or deceptive environmental assertions with the purpose of exploiting consumer preferences for environmentally friendly products and securing a larger portion of the market. However, using an event study methodology, the author observes that Chinese firms encounter statistically significant decreases in their stock prices, ranging from 2 to 3%, when their greenwashing practices are brought to light. The study demonstrates the concrete effects of greenwashing on consumer trust and the declines in the financial value of firms when they are discovered to have deceived stakeholders.

Parguel, Benoit-Moreau, and Larceneux (2011) have conducted a study that identified various factors that exert influence on the probability of a firm engaging in greenwashing practices. These factors encompass having a core business that is environmentally detrimental, possessing a negative environmental reputation, and exhibiting a dearth of transparency regarding its environmental impacts. These companies experience heightened pressure to manipulate external perceptions by employing deceptive tactics.

Nyilasy et al. (2014) demonstrated that the exposure of greenwashing practices has a detrimental impact on consumer perceptions. Surveys have also indicated a rise in consumer scepticism towards corporate environmental claims in general after the exposure of greenwashing practices, which entails a gradual decline in the confidence that consumers have in a particular entity or product (Vries et al., 2015),

In a more general framework, there is a broader contention that greenwashing practices have a detrimental impact on the overall public trust in environmental assertions put forth by corporations (Laufer, 2003; Ramus & Montiel, 2005). The proliferation of greenwashing engenders scepticism among consumers regarding the authenticity of sustainability claims made by companies. Further, the erosion of credibility poses a significant obstacle for companies that have genuine sustainability initiatives in their efforts to distinguish themselves among consumers and investors. In their study, Walker and Wan (2012) present empirical evidence using an event study methodology to examine the effects of greenwashing in the context of an environmental scandal. The authors find that although greenwashing may yield immediate financial advantages by reducing regulatory expenses, the negative consequences of reputational damage in the long run outweigh any short-term benefits. The authors contend that enhancing environmental performance in a substantial manner yields greater financial benefits for firms compared to the adoption of a greenwashing strategy. Szabo and Webster (2021) oddly conclude based on two sets of interviews, one with consumers interacting with a company's website and one with consulting firms that corporate communication affects consumers' happiness.

Environmental claims must be honest, sincere and a reflection of the organization's mission (Delmas & Burbano, 2011). Online forums such as *Greenwashingindex.com* appeared which allow consumers space to express concerns and raise questions about environmental claims. This theoretically makes it more difficult for companies to engage in dishonest claims about environmental impact actions. A more recent study (Marquis et al., 2016) used regression to test selective disclosure magnitude, i.e. the extent to which companies risk creating a misleading impression of transparency and accountability by disclosing relatively benign environmental metrics rather than those more representative of their overall environmental harm. Selective disclosure magnitude is calculated as the difference between two ratios that S&P Global Trucost developed to assess companies' environmental transparency; that is, absolute disclosure ratio minus weighted disclosure ratio. According to this methodology, a company's annual revenue is allocated to a subset of a standardized set of 464 industries based on data from public data aggregators, corporate annual reports, corporate regulatory filings, and feedback from the company, where available.

A more interesting development is a game-theoretic model of corporate social responsibility investment that we find with Wu et al. (2020). In this model, two types of firms are considered: those that are driven solely by profit maximization and those that are socially responsible, motivated not only by profit, but also by a genuine concern for the social good. The analysis examines how information transparency affects a firm's strategies and the social welfare, with the obvious finding that the higher the transparency, the better the strategy. An analysis of small medium enterprises from Saudi Arabia, with a questionnaire methodology shows that firms can become more efficient and improve their environmental performance through environment sustainable beliefs (Yousaf et al., 2023).

Recently we noted an increased interest of empirical studies towards linking ESG factors to the cost of capital—see Table 1. Piechocka-Kałużna et al. (2021) found that ESG and its components affect the cost of capital (weighted average, equity, and debt). Gonçalves et al. (2022) analysed the relationship between ESG performance and capital costs for the top European corporations listed on the STOXX Euro 600 index. They find that stronger ESG performance lowers equity costs but increases cost of debt. The cost of equity is penalized for firms with poor ESG performance compared to industry peers, and the industry median corporate sustainability performance score balances equity and debt costs. Equally interesting, sustainability performance affects businesses' cost of capital composition channels differently. In another study, Kumawat and Patel (2022) concluded that ESG disclosures were negatively correlated with cost of capital, interpreted by the authors as an effect of reduced information asymmetry. However, individual E, S, and G disclosure scores were insignificant.

Further, Phelan and Love (2023) propose a conceptual framework that establishes a connection between sustainability, economic growth, and the mitigation of risks associated with consumption. Their analysis focuses on the factors related to the production and availability of resources that affect sustainability. It emphasizes how a combination of higher economic growth and lower levels of resource consumption can contribute to improving the outlook for sustainability. These viewpoints have important consequences for investment strategies, risk management practices, and technology adoption in companies. Landi et al. (2022) conducted a longitudinal analysis from 2014 to 2018 to investigate how corporate social and environmental evaluations affect investors' perception of risk and market risk for companies that adopt sustainable strategies. According to their research, ESG assessments tend to increase the risk exposure of companies, especially due to their environmental performance. This indicates a level of ambiguity among investors regarding the long-term viability efforts of companies. The study conducted by Maaloul et al. (2023) examines the relationship between ESG performance, disclosure, corporate reputation, and the cost of debt. By employing Structural Equation Models (SEM) on data obtained from US S&P 500 companies, the researchers discover a direct correlation between ESG performance/disclosure and corporate reputation, indicating a positive relationship. Furthermore, they discover that an improved corporate reputation serves as an intermediary for reducing

Table 1 Studies on ESG and sustainable practices and firms' financing costs

Study	Period studied	Population studies	Main findings
Walker and Wan (2012)	2008	103 Canadian firms, various industries (chemical, energy, forestry, mining)	Substantive sustainable actions neither harmed nor benefited financial performance, but symbolic actions were related to decreased financial performance
Marquis et al. (2016)	2004–2007	4750 public companies from 45 countries, various industries	Firms with more environmentally damaging impacts are less likely to engage in selective disclosure when exposed to increased scrutiny and global norms
Hmaittane et al. (2019)	1991–2012	US firms belonging to controversial industry sectors (alcohol, tobacco, gambling, military, firearms, nuclear power, oil and gas, cement and biotechnology)	CSR engagement considerably lowers the implied cost of equity capital across all contentious industry sectors, both individually and collectively
Torelli et al. (2020)	2019	201 students, fictitious companies	Different levels of greenwashing significantly influence stakeholders' perceptions of corporate environmental responsibility and their reactions to environmental scandals
Houqe et al. (2020)	2008–2015	18,950 firms from 41 countries	ESG performance has a negative effect on firms' cost of debt
Piechocka-Kałużna et al. (2021)	2016–2020	US companies	ESG and its components affect the cost of capital, including the weighted average, equity, and debt costs
Maaloul et al. (2023)	2013–2016	S&P 500 companies	Positive effect of ESG performance and disclosure on corporate reputation, leading to lower cost of debt financing
Duong et al. (2023)	2009–2018	405 US firms	Effective carbon risk management following enhanced regulatory regime can lead to lower subsequent credit risk assessment and lower cost of borrowing
Gonçalves et al. (2022)	2002–2018	STOXX 600 companies	Strong ESG performance reduces equity costs but increases cost of debt

Table 1 (continued)

Study	Period studied	Population studies	Main findings
Kumawat and Patel (2022)	2011–2020	Indian NSE 500	ESG disclosures are negatively correlated with cost of capital; individual E, S, and G disclosure scores insignificant
Landi et al. (2022)	2014–2018	222 companies from S&P 500	ESG assessments increase firms' risk exposure, with environmental performance raising systematic risk
Rojo-Suárez and Alonso-Conde (2023)	2016–2020	Companies from Germany, France, Italy, Spain	ESG policies have minimal short-term effects but lead to lower value creation in the long run, primarily due to higher long-term discount rates
Ding and Shahzad (2022)	2015–2017	Manufacturing firms in Stock markets at Shanghai and Shenzhen stock exchanges in China	Environmental penalties increase corporate equity costs in the following year; disclosure increment mediates this effect
Khanchel and Lassoued (2022)	2011–2019	430 S&P 500 US firms	Shifting patterns in the impact of governance, social, and environmental disclosures on the cost of capital over time
Milani and Neumann (2022)	2015–2017	Top 2000 corporate R&D performers worldwide	Patenting activity attenuates the impact of negative internal liquidity shocks for relatively smaller firms, but not for relatively large companies
Ghitti et al. (2023)	2012–2017	500 largest US companies, by revenue	Greenwashing negatively affects firm' value
Fandella, Sergi, and Sironi (2023)	2014–2019	Companies from BRICS countries	Inclusion in the ESG combined index decreases the cost of equity and the average cost of capital instead
Mattera and Soto (2023)	February–March 2022	Spanish companies in the energy sector included in the Spanish IBEX-35 index	Long-term CSR commitments and ESG policies have a substantial impact on companies' ability to withstand crises and improve financial performance

Source: Authors' work

the cost of debt, suggesting potential advantages for companies that proficiently handle and reveal ESG information.

Rojo-Suárez and Alonso-Conde (2023) investigate the enduring impacts of environmental, social, and governance (ESG) policies on the worth of companies and the expenses associated with their ownership interests. According to their dynamic model, ESG strategies may have limited immediate effects but could result in reduced value generation in the long run due to elevated discount rates. This highlights the transitory effects of ESG strategies on equity costs and market value, urging firms to consider the long-term implications of their sustainability initiatives. Mattera and Soto (2022) offer an interesting perspective on the impact of CSR commitments and ESG strategies on the market value of Spanish firms in the energy sector in the months following the invasion of Ukraine. Their findings support a positive effect of firms' sustainable actions in the areas of CSR and embedded in ESG scores on their ability to endure crises, which is complementary to their beneficial influence on financial performance.

In their study, Ding and Shahzad (2022) examine the correlation between environmental fines, corporate environmental disclosures, and the equity cost. Their research demonstrates that penalties result in a rise in the expense of equity in the following year, with the disclosure increment serving as a mediator. The relationship between penalty-cost of equity and negative disclosure increments is strengthened, highlighting the significance of environmental management in the decision-making process of firm financing and adherence to regulations. Fandella et al. (2023) examine the correlation between the performance of corporate social responsibility (CSR) and the cost of capital in BRICS countries (Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Iran, and the United Arab Emirates). Their findings indicate that being included in the ESG combined index leads to a reduction in the cost of equity and the average cost of capital. There is a clear connection between corporate social responsibility (CSR) performance and decreased financial risk, emphasizing the importance of CSR activities in reducing capital risks, particularly in developing economies. In the same vein, Hmaittaine et al. (2019) investigated the relationship between CSR and cost of equity for Us firms that operate in several controversial industries and found that a solid corporate CSR engagement diminishes the cost of capital. Morevoer, the effect is more pronounced for firms in the alcohol and tobacco industry. Khanchel and Lassoued (2022) analyse the evolving correlation between ESG disclosure and the cost of capital by utilizing data from Standard & Poor's 500 companies in the United States. Their research uncovers changing trends in how governance, social, and environmental disclosures affect the cost of capital, highlighting the dynamic nature of corporate social responsibility (CSR) disclosure strategies and their consequences for firm risk management.

While there has been considerable research on the impact of corporate sustainable practices on financial performance, there is a significant research gap when it comes to examining the correlation between greenwashing and corporate financial performance. As late as 2014, efforts to associate greenwashing practices with financial performance emerged, where apparently greenwashing was significantly negatively associated with cumulative abnormal returns (Du, 2015). In this study, greenwashing, as measured by public information from widespread newspapers, correlated negatively with returns due to exposure of environmental wrongdoings, suggesting that the market punishes greenwashing through lower valuation. Otherwise, qualitative analysis continues to be the main analysis of greenwashing with effects on stakeholders' perceptions (Torelli et al., 2020). Therefore, our paper brings a valuable contribution to the quantitative empirical approach to the relationship between greenwashing and costs of capital, providing genuine findings in an emerging but very under-researched field.

3 Research methodology

Our paper addresses the link between controversies related to sustainability actions within corporations and the cost of capital for the global technology sector. This section of the study presents the data used in the empirical modelling and the panel econometric specifications employed to test the relationship between sustainability controversies and the cost of capital.

3.1 Data sampling and description

We collected the data for the global technology sector from Refinitiv for the period 2012–2021. However, after the initial data examination, the years 2012 and 2013 were dropped from the analysis, due to the few observations available. Hence, the investigation concerns the period 2014–2021. Since most previous works on the relationship between ESG ratings or scores and business performance spans over shorter periods (usually 3–5 years), the 8 years included in our research represents an important contribution to this research field. To be included in the analysis, companies had to have an ESG score in 2021.

The Reference data Business Classification (TRBC) of the London Stock Exchange Group (LSEG) was used to delineate the Technology sector. TRBC is a comprehensive and detailed classification of sectors and industries at global level and one of the classifications available in Refinitiv. A total of 692 listed companies was selected to be included in the analysis. They are distributed as follows across the Technology sector: (1) Telecommunication Services—158 companies; (2) Software & IT Services—498 companies; (3) Financial Technology (Fintech) & Infrastructure—22 companies; and (4) Technology Equipment—14 companies. These companies originate from 55 countries and all continents. Most companies come from the United States of America (243), China (73), Germany (35), United Kingdom (34) and Japan 932). For the remaining 51 countries the number of companies varies between 1 and 23. Overall, the dataset refers to 5,536 company-year observations. However, since not all companies enjoyed full data for each variable, the resulting data panel is unbalanced.

Data refers to four main types of variables: (i) Cost of capital variables—specifically, we collected information on the weighted average cost of capital (WACC), cost of equity (COEQ) and cost of debt (COD); (ii) Controversies variables—ESG Controversies (ESGCV) and Environmental Controversies (ENVCV): (iii) Sustainability measures—ESG and ENV scores; (iv) Control variables—profitability (EBIT margin, EBITMG), business size (Market capitalization, SIZE), indebtedness ratio (Ratio of total debt to total equity, LEV), and management performance towards governance principles (Management score, MNGS). All data was collected from LSEG-Refinitiv. We briefly present these variables in Table 2. All variables have been selected based on the research objectives of the study and previous works. They are further explained below.

Dependent variables. Our research interest pertains to the impact of greenwashing on firms' cost of capital as a measure of business performance. The cost of capital is one of the most comprehensive metrics of corporate performance and financial health, as it represents the lowest return a company must make on existing assets to satisfy investors (Brealey et al., 2020). Moreover, the cost of capital is intrinsically connected to the underlying financial and operational risks faced by the company, as lenders and shareholders apply risk premiums when calculating their expected rates of return (Ross et al., 2022).

Table 2 Variable description

Notation	Variable	Brief description	Measure
Dependent variables			
WACC	Weighted average costs of capital	The measure of company's total cost of capital in which each category of capital (equity, preferred stock and debt) is proportionately weighted	Percentages
COEQ	Cost of equity	The return a firm theoretically pays its equity investors, calculated by multiplying equity risk premium of the market with the beta of the stock plus an inflation adjusted risk free rate. The equity risk premium is the expected market return minus inflation adjusted risk free rate. The calculation of the cost of equity is based on the Capital Asset Pricing Model (Sharpe, 1964)	Percentages
COD	Cost of debt	The marginal cost to the company of issuing new debt, calculated by adding the weighted costs of short term debt and long term debt based on the 1- and 10-year horizons of the yield curve	Percentages
Main independent variables			
ESGCV	ESG Controversies	Measure of a company's exposure to environmental, social and governance controversies and negative events reflected in global media. Ranges between 0 and 100. A higher score indicates more controversies around the company	Points
ENVCV	Environmental Controversies	Measure of a company's exposure in the media because of controversies linked to the environmental impact of its operations on natural resources or local communities. Ranges between 0 and 100. A higher score indicates more controversies around the company	Points
Sustainability measures			
ESG	ESG Score	Overall ESG score calculated by Refinitiv based on companies' self-reported information in the environmental, social and corporate governance pillars. Ranges between 0 and 100. A higher score designates superior sustainability performance	Points
ENV	Environmental Score	The environmental component of the ESG score, which analyses a company's influence on living and non-living natural systems, such as air, land, and water, as well as entire ecosystems. It embodies a company's ability to adopt best management practices to prevent environmental risks and benefit from environmental opportunities to generate long-term shareholder value. Ranges between 0 and 100. A higher score designates superior environmental performance	Points
Control variables			
PROF	EBIT margin	Masure of profitability: the ratio of EBIT (Earnings before interest and taxes) and total revenues, in percentages. A higher value indicates better profitability and improved cost management	Percentages

Table 2 (continued)

Notation	Variable	Brief description	Measure
SIZE	Market capitalization	Measure of size: total market capitalization of companies. A higher value indicates a higher size of the company	US dollars billions
FLEV	Financial leverage	Measure of indebtedness: ratio of total debt to total equity. A higher value indicates more indebtedness and decreased solvency	Percentages
MNG	Management score	Refinitiv measure of a company's managerial commitment and effectiveness towards governance principles. Ranges between 0 and 100. A higher score designates superior managerial performance	Points

Source: Authors' work

Companies that struggle with weak competitive positions on the market, outdated and deficient business models, and/or high indebtedness carry higher risks, which translate into superior expected returns by investors. Therefore, the cost of capital acts like a barometer for changing business conditions, competitiveness and risk dynamics over time and its tracking by executives facilitates informed risk assessment and resource allocation.

We measure a company's cost of capital using three indicators calculated by Refinitiv: Weighted average cost of capital (WACC), the Cost of equity (COEQ) and the Cost of debt (COD). While COEQ and COD provide insight into the cost of money required by different investor categories—debtholders and shareholders—, the WACC shows the combined cost of money paid by the firm to all investors, proportionally weighted with each source of financing at its market value, for long-term and short-term business projects and operations. By using the costs associated to different investor categories, which are interested in distinct business and financial risks at firm level, we explore potential contrasts related to the effect of sustainability and environmental greenwashing on the price that firms pay to obtain financing from financial institutions and markets. As outlined in the Literature review section, several previous studies have used the weighted average cost of capital, cost of equity and cost of debt in their investigations related to corporate sustainability practices—see, for example, Piechocka-Kałużna et al., 2021; Gonçalves et al., 2022; Kumawat & Patel, 2022.

Main independent variables. The main independent variables used in our work are proxies for sustainability and environmental greenwashing. First, we estimate the level of firms' overall sustainability greenwashing by ESG Controversies Score (ESGCV) is a measure of a firm's involvement in negative ESG-related news and media mentions. Refinitiv calculates this score by aggregating information from media references to a company that are associated with ESG issues, and then weighting these by the impact of references based on publications' reach, audience, and engagement in social media (LSEG, 2023). This score helps investors identify companies that are at risk of reputational damage or regulatory action due to their involvement in ESG controversies, but it can also be used to track a company's progress in addressing ESG issues. We use ESGCV as a measure of sustainability greenwashing at corporate level following several recent works in the existing literature. For example, Xue et al. (2023) consider that the ESG Controversy Score mitigates concerns related to superficial sustainability initiatives aimed at artificially enhancing ESG performance, because it is difficult for companies to disguise scandals covered in the media. Also, Ghitti et al. (2023) use the ESG Controversy Score as a measure of ex-ante orienting direction in greenwashing.

One of the 10 components of the ESG Controversies Score is the Environmental Controversies Score, which measures the environmental impact of company's involvement in negative environmental-related news and media mentions. We employ this score (ENVCV) to account for the extent of corporate environmental greenwashing, distinct from the overall sustainability greenwashing. Very few studies have used this approach so far to measure the distinct environmental leg of corporate greenwashing. We thus add to the insights offered by Burkhardt et al. (2020), Oscar et al. (2022) and Wu et al. (2023) on environmental controversies.

Sustainability variables. The impact of corporate greenwashing on business performance measured by the cost of capital, either at the overall sustainability level or in relation to the environment, cannot be fully captured and understood without considering firms' initiatives and strategies towards sustainability and environmental protection. Therefore, our models include the ESG Score (ESG) and the Environmental Score (ENV) as measures of corporate sustainability, following similar approaches in the literature—see, among many others, Sahut and Pasquini-Descomps (2015), Pellegrini et al. (2019), Kalia and Aggarwal (2023), Lee et al. (2023).

Control variables. The impact of greenwashing on the cost of capital is moderated by several firm-level parameters, which are considered as control variables. First, we measure firm size (SIZE) by market capitalization, which we consider a better measure than corporate assets. The global nature of our sample of companies makes the use of corporate assets, denominated in different currencies and less comparable across countries, less relevant for measuring size compared to market capitalization, based on stock prices of companies traded in exchanges around the world. Previous research that firms size is a key factor in greenwashing behaviour, with larger companies more likely to engage in this practice (Li et al., 2023). In the same vein, Wickert et al. (2016) report that larger size stimulates greenwashing, while Kim and Lyon (2015) show that greenwashing increases with corporate growth. On the other hand, Du (2015) suggested that larger companies may face greater scrutiny and potential backlash for greenwashing, implying that investors penalize companies for engaging in this practice. Second, business profitability is considered as a control variable, measured by the EBIT margin (PROF). Roulet and Touboul (2015) found that lower profitability is an incentive to greenwashing, but several studies have also suggested that companies' engaging in greenwashing can backfire, destroying reputation, value and profitability (Hameed et al., 2021; Walker & Wan, 2012).

The third control variable refers to corporate indebtedness, which we measure by the ratio of total debt to total equity capital (FLEV). We consider total debt in calculating this ratio due to the cost of debt calculated by LSEG-Refinitiv, which considers both long and short-term sources of financing. Highly indebted enterprises may engage in greenwashing to attract investors and improve their creditworthiness. Also, high-indebtedness corporations may also be pressured by lenders and creditors to enhance their ESG performance, which could lead to greenwashing (Zhang, 2022). The last control variable that we use in our models is related to managerial performance towards sustainability (MNG), building on existing research that emphasizes the relevance of top management commitment as well as resource commitment in boosting a firm's green practices and performance (Richey et al., 2014). Guo et al. (2020) also stresses the favourable influence of managers' assigned responsibility on green sustainable behaviours, with waste management acting as a moderator. However, this commitment can also lead to greenwashing, particularly when influenced by investors' preferences, which may result in symbolic actions without substantive change (Barrymore, 2022).

3.2 Empirical model

Based on their widespread use in the empirical literature, we used panel regression models to capture the relationship between greenwashing and the cost of capital in the Technology sector. After Baltagi seminal work on panel data modelling (Baltagi, 2005) opened the road, many scholars used panel data modelling to control heterogeneity and estimate variable connections more efficiently, especially in smaller samples (Pesaran, 2015). Over time, several panel regression specifications were developed and used in empirical research. We used dynamic panel modelling with a Generalized Method of Moments (GMM) specification, which became widely utilized in econometric analyses due to their ability to address endogeneity and omitted variable biases. As Arellano and Bond (1991) groundbreaking research demonstrated, the GMM estimator controls for the potential endogeneity of explanatory variables by using their lagged values as instruments. Additionally, it allows the inclusion of firm-specific effects, thereby accounting for unobserved heterogeneity across cross-sectional units. As Blundell and Bond (1998) discuss, this makes dynamic panel GMM well-suited for studying economic relationships with persistent dependent variables when factors influencing the predictors are present but difficult to directly measure. Moreover, the dynamic panel GMM methodology is suited for panel data analysis in unbalanced datasets and imposes discipline by requiring that models stand up to specification testing, including on the validity of instruments (Roodman, 2009). This helps ensure accurate coefficient estimates that support causal interpretation. Through Monte Carlo simulations, Kiviet (1995) also verified the consistency of the GMM estimator even for small sample sizes and minimal time periods. This flexibility enables researchers to explore dynamics using short macroeconomic or microeconomic panels where conventional estimators break down.

Dynamic panel GMM models can be estimated as difference or system-GMM. The system-GMM adds extra moment conditions to the difference-GMM which are reflected in substantial efficiency gains (Bond, 2002). In their research, Blundell and Bond (1998) demonstrated that system-GMM has far lower bias and variance than difference-GMM estimators, which translates in improved results of significance and model specification tests. Additionally, two-step efficient GMM flows logically from one-step estimation by iteratively weighting the moment conditions to arrive at a covariance matrix robust to heteroskedasticity and autocorrelation. Windmeijer's (2005) correction then alleviates the downward bias in two-step standard errors. This finally permits more accurate inference by tightening hypothesis testing and confidence intervals around coefficient estimates. However, as cautioned by Roodman (2009), employing too many instruments can overfit endogenous variables and weaken specifications in system-GMM, requiring judicious balancing of efficiency against instrument proliferation. Taking these into consideration, we implemented the models in Stata 18.0 using the 'xtdpdgmm' command developed by Kripfganz (2019) that incorporates the Windmeijer's correction and allows for instrument collapse. All models were estimated in the one-step and two-step system-GMM framework, but the results are highly similar; hence, we report only the one-step findings.

The general specification of the models used in our investigation is presented in Eq. (1).

$$Y_{it} = \alpha_{it} + \varphi_{it} Y_{it-1} + \beta_{it} G_{it} + \gamma_{it} S_{it} + \delta_{it} C_{it} + \theta_{it} + \varepsilon_{it} \tag{1}$$

In this equation, Y_{it} designates the cost of capital variables (WACC, COEQ, COD), Y_{it-1} is the one-lag of the dependent variable, G_{it} represents the greenwashing variables (ESGCV and ENVCV), S_{it} stands for sustainability variables (ESG and ENV), and C_{it} is the vector of control variables (PROF, SIZE, FLEV, MNG). Additionally, α_{it} is the intercept, θ_{it} indicates time effects, and ϵ_{it} is the model error. The panel regression coefficients estimated by our models are β_{it}, γ_{it}, and δ_{it}. Time (t) is between 1 and 8 (from 2014 to 2021) and i is the number of firms included in the estimations, which varies from one model to another due to data unavailability.

In testing the effect of greenwashing of firms' cost of capital we proceeded as follows: first, we estimated the models only with the greenwashing variables included, to observe their direct impact on the cost of capital; second, we added in the models the sustainability variables, to identify a potential controlling effect from them on greenwashing—i.e., if firms with better sustainability and environmental performance also engage in more greenwashing. This approach also served as a robustness check for the greenwashing results. All models included all control variables, except for models where COD was the dependent variable that excluded MNG due to second-order correlation in residuals. To perform the estimations, we worked with the natural logarithms of variables, thus increasing the normality properties of the variables' distributions.

Besides carrying out the investigation on the entire panel dataset, we were interested in examining potential differences related to the relationship between greenwashing and the cost of capital for firms with high versus low systematic risk, i.e., how much does a stock return move for a given change in market return. The rationale behind this approach is related to the growing awareness of investors, governments and general public about sustainable practices, which pressured companies to engage in greenwashing. Systematic risk refers to exposures to economy-wide factors that cannot be diversified away, causing assets to follow broader market turns. As Lydenberg and Sinclair (2009) describe, greenwashing erodes stakeholder trust if dubious claims unravel, elevating the issuer's equity beta—the wide-acknowledged systematic risk metric. Consequently, investors may penalize firms engaged in greenwashing through higher costs of equity that persistently destroy value. Gregory (2023) discovered, however, that when company stock volatility is low, the financial incentives for greenwashing are high. Nevertheless, research that addressed the relevance of systematic risk for greenwashing is strongly lacking, which makes our study a pioneering endeavour.

We constructed two sub-panels based on beta values collected from LSEG-Refinitiv—the platform uses the CAPM model (Sharpe, 1964) to calculate beta. For each company we calculated the average beta over the 2014–2021 time span and then divided the firms in high-beta versus low-beta sub-panels based on the median of these average betas, i.e., the high-beta panel includes firms with betas higher than the median and the low-beta panel includes firms with betas lower than the median.

In order to assess the reliability of our dynamic panel GMM estimations, we utilized the Arellano-Bond serial test of second-order correlations in residuals (Arellano–Bond, 1991) and the overidentifying restrictions test introduced by Sargan (1958) and Hansen (1982). For the models to be valid the Arellano–Bond serial has to show *p*-values for AR(1) below 0.05 and for AR(2) above 0.05. The Sargan–Hansen test indicates the lack of overidentifying restrictions if *p*-value is above 0.05.

4 Results and discussion

This section of the paper presents the main findings of our investigation and discusses them against previous results in the literature, if available. We start by briefly presenting the descriptive statistics and the correlation matrix for all variables.

4.1 Descriptive statistics and preliminary analysis

Table 3 shows the descriptive statistics for all variables. The variables designating the cost of capital show that, on average, firms in the Technology enjoyed costs of equity of 8.2%, costs of debt of 2.3% and a WACC of 7.4%. The closeness of WACC to COEQ suggests that the financial leverage was moderate, as indicated by the mean FLEV of 1.044. However, the standard deviations, as well as the minimum and maximum values, point towards variability within the dataset. When looking at ESGCV and ENVCV, both show means that are moderate in value, although slightly higher for ESGCV (54.179 against 44.874). This may suggest that strict environmental greenwashing was accompanied by other sustainability greenwashing pertaining to social and/or governance actions. Variation is also

Table 3 Descriptive statistics of variables

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
WACC	4885	0.074	0.038	− 0.075	0.515
COEQ	4887	0.082	0.042	− 0.103	0.538
COD	4885	0.023	0.022	− 0.006	0.546
ESGCV	4105	91.199	22.617	0.385	100
ENVCV	4105	54.179	3.467	0.000	55.713
ESG	4105	44.874	19.901	0.910	94.502
ENV	4105	27.915	27.096	0.000	91.305
PROF	5367	− 0.719	24.621	− 1404.97	12.305
SIZE	5070	21.20	106.00	4859.90	2900.00
FLEV	5107	1.044	6.789	0.000	422.1
MNG	4105	51.933	28.420	0.092	99.938

Source: Authors'work

present for these variables, in the case of ESGCV several companies reaching to 100 (the maximum possible value), indicating significant media exposure in relation to sustainability practices. In terms of sustainability, ESG and ENV record rather small means (44.87 and 27.915, respectively), which is a sign of reduced involvement of firms in this sector in environmental and sustainable actions. Again, these means are accompanied by important variation.

The correlations between variables and their statistical significance are presented in Table 4. As expected, all types of costs of capital (WACC, COEQ and COD) are positively and statistically significantly correlated between themselves. Sustainability greenwashing (ESGCV) and environmental greenwashing (ENVCV) are positively and statistically significantly correlated, but ESGCV is correlated with WACC (positive correlation) and COD (negative correlation). On its turn, ENVCV is positively correlated with all types of cost of capital, but without statistical significance. These suggest that more greenwashing was associated with higher cost of capital. When we turn to sustainability variables, they are mostly negatively correlated with cost of capital, directing towards a reduced cost of capital for companies with more consistent sustainability practices—to note, though, the positive ENV–COD correlation. Control variables show different patterns in their correlations with both costs of capital and greenwashing variables. There seems to exist a positive association between cost of capital and profitability, as well as financial leverage, while the association is negative for size and management performance towards sustainability. At the same time, all control variables show negative correlations with greenwashing variables. The level of correlations indicates that variables can be safely included in the same model.

We further dissect the evolution of cost of capital in the Technology sector between 2014 and 2021 (Fig. 1). First, we note the remarkably low cost of debt paid by these firms until 2020 (below 3% and even below 2% in 2019), fuelled by very low interest rates across the world. In 2021 the cost of debt increased to reach, on average, 4.35%, a reflection of increased debt accumulations and default risks caused by the Covid-19 pandemic. COEQ followed the same pattern of decline until 2020, varying between 9.46% in 2017 and 6.06% in 2020, to rise to an average of 9.90% in 2021. The WACC, as the average of the two, followed through, but it never went above 9% for the sector, on average.

Table 4 Correlation matrix

	WACC	COEQ	COD	ESGCV	ENVCV	ESG	ENV	PROF	SIZE	FLEV	MNG
WACC	1.000										
COEQ	0.903*	1.000									
COD	0.212*	0.221*	1.000								
ESGCV	0.044*	− 0.009	− 0.066*	1.000							
ENVCV	0.0165	0.021	0.016	0.196*	1.000						
ESG	− 0.114*	− 0.051*	− 0.001	− 0.247*	− 0.046*	1.000					
ENV	− 0.145*	− 0.061*	0.011	− 0.291*	− 0.061*	0.804*	1.000				
PROF	0.015	0.021	0.033*	− 0.011	− 0.003	0.032*	0.031*	1.000			
SIZE	− 0.025	− 0.037*	− 0.005	− 0.405*	− 0.399*	0.199*	0.211*	0.076*	1.000		
FLEV	− 0.022	0.016	0.076*	− 0.055*	0.000	0.026	0.045*	0.005	− 0.002	1.000	
MNG	− 0.077*	− 0.027	− 0.022	− 0.094*	− 0.032*	0.687*	0.340*	0.025	0.119*	− 0.001	1.000

*Denotes statistical significance at 5%

Source: Authors'work

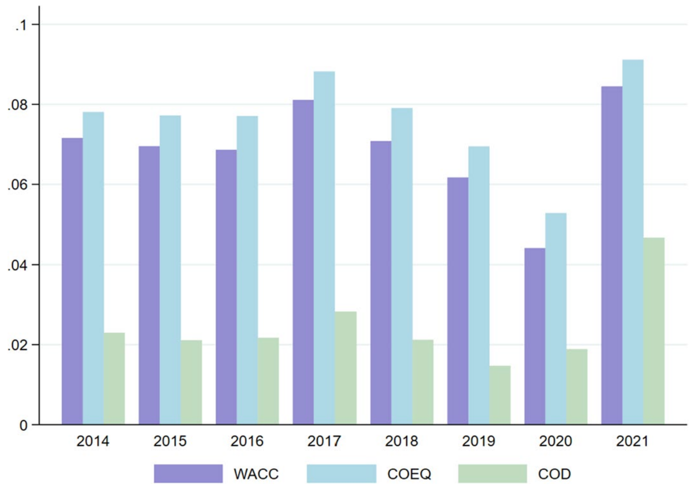

Fig. 1 Cost of capital in the Technology sector, 2014–2021 (median values). Source: Authors'work

When turning to greenwashing and sustainability (Fig. 2) over the timeframe of our analysis, we see that sustainability greenwashing (ESGCV) was at much higher levels than environmental greenwashing (ENVCV). However, a slight increase in ENCV is noticed after 2017, while ESGCV tends to decrease slowly after 2018. The overall mean performance of Technology firms in sustainability (ESG) varied between 41.756 in 2017 and 51.054 in 2021, while their environmental performance (ENV) recorded substantially lower means, varying between 24.167 in 2017 and 33.411 in 2021. Both metrics declined between 2014 and 2017 and further increased until 2021. This may

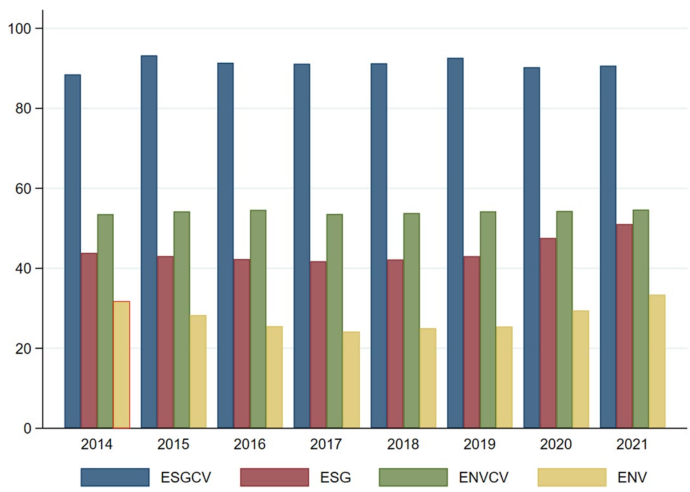

Fig. 2 Greenwashing and sustainability in the Technology sector, 2014–2021 (means)

be explained by the sustained interest of investors in sustainability and the significant development financing needs of businesses in this sector.

Concerning the sub-panels based on systematic risk, we note that the median beta of all Technology firms for the 2014–2021 timeframe was 0.962, very close to the beta benchmark of one (market beta). For the high-beta firms, the mean beta over our time span was 1.307 and the median was 1.205, while the median and mean betas for the low-beta panel were 0.722 and 0.687, respectively.

4.2 Estimation results, discussions and implications

Tables 5 to 10 present the results of the dynamic panel one-step system-GMM estimations. Two-step estimations were also performed, but results are highly similar, therefore we report only the one-step estimates. For each type of cost of capital—WACC, COEQ and COD—we show the results in two tables, one for sustainability greenwashing impact on cost of capital (ESGCV as the main independent variable) and one for environmental greenwashing effect (ENVCV as the main independent variable). In each table, the first two columns of estimates refer to all companies and the remaining four columns show estimates for the high-beta and low-beta sub-panels, respectively. Models were implemented first only with the greenwashing variables and then they were complemented with the sustainability variables. Overall, 36 dynamic panel GMM models were estimated. Since data was used in the models in logarithmic form, the regression coefficients can be interpreted as elasticities.

The regression coefficients in Table 5 and 7 clearly indicate that sustainability greenwashing, proxied by LESGCV, pays off for firms in the Technology sector in the form

Table 5 GMM estimation results for sustainability greenwashing—LWACC dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	1	2	3	4	5	6
LWACC, 1 lag	0.678***	0.677***	0.579**	0.498**	0.549***	0.574***
LESGCV	– 0.008***	– 0.008**	– 0.016***	– 0.018***	– 0.008	– 0.005
LESG	–	– 0.002	–	– 0.007	–	0.001
LPROF	– 0.048**	– 0.048**	0.000	0.000	– 0.092***	– 0.102***
LSIZE	0.026**	0.029***	0.026	0.035*	0.031**	0.001
LFLEV	0.035***	0.038***	0.035**	0.045**	0.036**	– 0.005
LMNG	– 0.039***	– 0.0428***	– 0.045**	– 0.057**	– 0.042***	– 0.006
Constant	0.000***	0.000***	– 0.121	– 0.158	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	516	516	261	261	255	255
Number of instruments	24	27	24	27	24	27
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.782	0.796	0.618	0.572	0.761	0.972
Hansen-Sargan statistic (*p*-value)	0.139	0.127	0.129	0.153	0.268	0.037

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

of reduced cost of equity and WACC. Regression coefficients show that a 1% increase in ESGCV leads to a 0.11% decline in cost of equity and an 8% decline in WACC. These results are confirmed in the presence of ESG as a measure of business sustainability, although the coefficients for LESG are not statistically significant. This effect retains significance but becomes more pronounced among Technology firms exhibiting higher sensitivity to broad market movements, captured by beta. While for the firms in the low-beta panel the impact of a 1% change in ESG on cost of equity is similar to the overall panel, companies in the high-beta panel enjoy an amplified effect—for them, a 1% change in ESGCV leads to a 0.24% decrease in cost of equity. For WACC the pattern is comparable, only that the decline in WACC is slightly lower 0.16–0.18% (depending on whether ESG is included in the model or not). This difference is easily explained by the weighted importance of cost of equity in WACC. It is important to note that for WACC panels, low-beta firms retain the regression coefficients' sign for high-beta firms, but not the statistical significance.

We interpret these findings as a sustained focus of market investors on Technology firms enjoying high-growth rates, but also being exposed to high risks, which were ready to ignore sustainability scandals to grasp the returns provided by innovation and technology. The magnitude of the relationship between projected strengthened sustainability efforts and reduced equity costs aligns intuitively with the Technology sector, given these companies' disproportionate reliance on issuing common stock to fund expansive R&D budgets, fast-paced innovation cycles, and pursuit of growth opportunities (Othman & Ameer, 2014; Milanni & Neumann, 2022). Hence, investors in technology provide capital under high uncertainty about cash flow time horizons, meaning financial transparency and cues about management's capacity to address emergent risks carry heightened importance. Furthermore, by adopting sustainability measures, Technology companies may gain legitimacy with both investors and customers that increasingly demand ethical conduct, widening stakeholders' acceptance and improving access to financing on attractive terms (Ambec & Lanoie, 2008). However, if technology firms couple sustainability efforts with disclosures revealing genuine traction and impact from these programs rather than superficial communications sometimes characterized as "greenwashing", then the observed reductions in equity capital costs logically follow within mainstream financial theory.

Contrary to cost of equity and WACC, increased sustainability greenwashing activities, captured by ESGCV, are linked to heightened debt costs (see Table 9). This finding is valid for all firms panel and for both beta-based sub-panels, although no significant difference in the effect of greenwashing on cost of debt is revealed—a 1% increase in ESGCV leads to 4.6–4.9% increase in the cost of debt. Lending institutions estimate the default risk of borrowers considering the latter's financial performance and are interested in objective and demonstrable information referring to capital structure and leverage, along with liquidity and profitability to properly assess firms' ability to reimburse their debt (Levitt, 1958). At the same time, several works have emphasized that engaging in sustainable practices as a cover for corporate misbehaviour (or greenwashing) results in a riskier profile and a higher cost of debt (Carey et al., 2021; Gray, 2010; Jensen & Smith, 1985). Our data shows that while debt played a less prominent (though still important) role in Technology companies' capital structures than equities until 2017 (the mean FLEV for all companies in our sample declined from 0.780 in 2014 to 0.756 in 2016, further increasing to 0.924 in 2017 but still indicating a reduced weight of debt in capital structures than equity), its ratio to equity in financing the sector jumped to 1.519 in 2018 to slowly decline until 2021 (1.092). However, these changes in capital structure have not been reflected in increasing costs of debt after 2018, as inflation rates globally have reached very low levels. In 2021, though, the mean cost of debt increased to 4.3%, impacted by surges in inflation due to the Covid-19

Table 6 GMM estimation results for environmental greenwashing—LWACC dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	7	8	9	10	11	12
LWACC, 1 lag	0.654***	0.661***	0.458***	0.474***	0.676***	0.661***
LENVCV	0.001	− 0.146***	− 0.006	− 0.124*	0.010	− 0.139**
LENV	–	0.154***	–	0.125*	–	0.149**
LPROF	− 0.067***	− 0.053***	0.000	0.000	− 0.070***	− 0.065***
LSIZE	0.025**	0.023**	0.028*	0.029***	0.024**	0,021*
LFLEV	0.034**	0.037**	0.032	0.040*	0.036*	0.034*
LMNG	− 0.036**	− 0.040**	− 0.043**	− 0.050**	− 0.035**	− 0.035**
Constant	0.000***	0.000***	− 0.316***	− 0.265**	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	557	557	282	282	275	275
Number of instruments	18	20	18	20	18	20
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.641	0.615	0.314	0.269	0.653	0.690
Hansen-Sargan statistic (*p*-value)	0.106	0.137	0.433	0.112	0.164	0.034

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

Table 7 GMM estimation results for sustainability greenwashing—LCOEQ dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	13	14	15	16	17	18
LCOEQ, 1 lag	0.741***	0.738***	0.541***	0.532***	0.675***	0.669***
LESGCV	− 0.011***	− 0.011***	− 0.023***	− 0.024***	− 0.011*	− 0.011*
LESG	–	0.005	–	− 0.001	–	− 0.009
LPROF	− 0.018	− 0.019	0.000	0.000	− 0.038*	− 0.042**
LSIZE	0.015*	0.016**	0.011	0.013	0.0176*	0.018*
LFLEV	0.032***	0.034***	0.037**	0.039***	0.0034**	0.036**
LMNG	− 0.027***	− 0.029***	− 0.031**	− 0.034**	− 0.030**	− 0.021**
Constant	0.000***	0.000***	− 0.059	− 0.060	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	516	516	261	261	255	255
Number of instruments	24	27	24	27	24	27
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.561	0.567	0.561	0.681	0.583	0.616
Hansen-Sargan statistic (*p*-value)	0.111	0.132	0.311	0.210	0.286	0.326

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

Table 8 GMM estimation results for environmental greenwashing—LCOEQ dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	19	20	21	22	23	24
LCOEQ, 1 lag	0.745***	0.747***	0'.465***	0.489***	0.841***	0.819***
LENVCV	0.015	− 0.129***	0.006	− 0.113	0.022	− 0.135**
LENV	–	0.151***	–	0.128	–	0.156**
LPROF	− 0.041***	− 0.028**	0.000	0.000	− 0.024	− 0.019
LSIZE	0.013	0.011	0.010	0.011	0.013	0.008
LFLEV	0.029**	0.032**	0.029	0.034*	0.029*	0.026*
LMNG	− 0.023**	− 0.026**	− 0.022*	− 0.028	− 0.023*	− 0.021*
Constant	0.000***	0.000***	− 0.285***	− 0.231**	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	557	557	282	282	275	275
Number of instruments	18	20	18	20	18	20
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.734	0.675	0.364	0.302	0.708	0.757
Hansen-Sargan statistic (*p*-value)	0.061	0.051	0.196	0.101	0.307	0.044

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

Table 9 GMM estimation results for sustainability greenwashing—LCOD dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	25	26	27	28	29	30
LCOD, 1 lag	0.621***	0.623***	0.525***	0.525***	0.689***	0.690***
LESGCV	0.049***	0.049***	0.046***	0.0467***	0.043**	0.042**
LESG	–	− 0.021	–	− 0.018	–	− 0.026
LPROF	− 0.284***	− 0.277***	0.000	0.000	− 0.026***	− 0.253***
LSIZE	0.016**	0,016**	0.004***	0.005	0.020	0.021
LFLEV	0.021***	0.021***	0.031***	0.031***	0.013	0.012
Constant	0.000	0	− 0.912***	− 0.906***	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	576	576	286	286	290	290
Number of instruments	16	18	16	18	16	18
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.071	0.071	0.423	0.417	0.086	0.087
Hansen-Sargan statistic (*p*-value)	0.264	0.324	0.360	0.481	0.583	0.605

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

pandemic and long-lasting quantitative easing policies (Bobeica & Hartwig, 2023; Brown, 2015). Therefore, we might imply from our results that debtholders became more alert in relation to Technology firms' cost of capital, but further identifying the conditions under which sustainability shifts translate into Technology sector's debt risks merits additional investigation with the aim of maximizing the financial system's ability to redirect resources toward ethical and sustainable business activities (Houqe et al., 2020).

Turning to environmental greenwashing, results reported in Tables 6, 8 and 10 show that firms in the Technology sector have successfully used information disclosure about their environmental practices, including media coverage of environmental issues, to decrease their costs of capital. Although all regression coefficients for ENVCV, our measure of environmental greenwashing, are negative in all models, we note an interesting difference between cost of equity and cost of debt, on the other hand. For all companies' panels, ENVCV shows negative and statistically significant coefficients in both models (with and without ENV), suggesting that a 1% increase in ENV leads to declines in the cost of debt of 16–18%. However, the increase in the cost of equity generated by ENVCV is smaller (13.5%) and the coefficient is statistically significant only when ENV is included in the model. At WACC level the decline is 14.6% at a 1% increase in environmental greenwashing, also when ENV is included in the model. For the two beta-based panels, the discount on the cost of debt is higher for firms with higher systematic risk (16.7 versus 12.4%), but the situation is reversed for cost of equity—13.5% decline for low-beta firms versus 11.5% for high-beta firms and the latter is not statistically significant. At WACC level reductions are of 14.6% for all companies panel, with a slight edge for low-beta firms (13.9 versus 12.4%) and also under the presence of ENV.

Rather surprisingly, all coefficients for ENV are positive across models and statistically significant, except the ones referring to cost of debt, which are not statistically significant. This hints towards investors connecting heightened corporate actions towards

Table 10 GMM estimation results for environmental greenwashing—LCOD dependent variable

Variables	All companies, 2014–2021		High beta, 2014–2021		Low beta, 2014–2021	
	31	32	33	34	35	36
LCOD, 1 lag	0.643***	0.643***	0.511***	0.511***	0.721***	0.720***
LENVCV	− 0.164***	− 0.186**	− 0.167***	− 0.120	− 0.124**	− 0.234
LENV	–	0.211	–	− 0.047	–	0.110
LPROF	− 0.111***	− 0.110***	0.000	0.000	− 0.109***	0.103***
LSIZE	0.005	0.005	− 0.004	− 0.002	0.009	0.008
LFLEV	0.029***	0.029***	0.042***	0.043***	0.018**	0.018**
Constant	0.000	0.000	− 0.441***	− 0.455***	0.000	0.000
Yearly effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of groups	619	619	306	306	313	313
Number of instruments	16	18	16	18	16	18
AR(1) *p*-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) *p*-value	0.093	0.093	0.426	0.424	0.129	0.129
Hansen-Sargan statistic (*p*-value)	0.041	0.044	0.190	0.287	0.383	0.284

***, ** and * denote statistical significance at 1%, 5% and 10%, respectively. Source: Authors'work

environmental protection or more sustained environmental activities with increased costs of financing. Several explanations may be advanced for this result. First, transforming operations and supply chains to be more sustainable often requires major upfront investments in clean energy infrastructure, eco-efficient factories, green transportation fleets, etc. These lead to higher investor uncertainty regarding corporate environmental performance, which leads to increases in systematic and specific risks and are reflected in rising costs of capital (Landi et al., 2022). Second, product lifecycles in the Technology sector tend to be shorter compared to other sectors, as indicated by the frequent turnover in both hardware and software products (Thornhill, 2006). This means that firms in the Technology sector have less certainty that green and environmental investments will pay off before the next generation of products cannibalize older ones, with impact on business risks and higher returns required by investors. Third, the most important players in the Technology sector use huge data centres and cloud infrastructure to accommodate surging energy demand; however, achieving carbon neutrality requires major cloud efficiency investments at long-term and uncertain cost, which translate into higher financing needs and increased costs of financing.

For what concerns the results associated with control variables, they are homogeneous across estimated models. We find a negative relationship between firms' profitability (PROF), measured by EBIT margin, and all types of cost of capital. When comparing this relationship for cost of equity and cost of debt, we find it to be stronger for the cost of debt. This result is in line with finance logic that sees more profitable firms facing lower costs from raising financing (Brealey et al., 2020). Thus, highly profitable firms with good management of costs signal lower risk to investors, reducing required rates of return and costs to issue stocks and bonds. Also, robust earnings enable firms to rely more on retained profits rather than external capital, avoiding financing expenses (Drobetz & Wanzenried, 2006). It is also interesting that our findings point towards a negative relationship between profitability and cost of capital for low-beta firms, but not for high-beta firms, which means that a firm's level of systematic risk is relevant for this connection. Only firms with business models resilient to systematic, economy-wide shocks can sustain reliable profit streams that minimize investors' risk premiums (Gulec & Karacaer, 2017).

When business size is considered, we find that scale is positively related to costs of capital. Although this result is counterintuitive, as larger firms benefit from economies of scale in operations and financing which make them afford greater bargaining power over resources, enabling investment in price-hedging strategies to mitigate financing costs and cash flow unpredictability (Shil et al., 2019). Their scale also provides more visibility, credibility, and liquidity to attract investors under less costly terms (Hao & Li, 2021). However, for firms in the Technology sector the relationship between size and financing costs may be challenged and goes into positive territory because larger companies manage complex product and services portfolios that may be difficult to pivot when economic trends are shifting (Fernhaber & Patel, 2012). At the same time, many companies in this sector rely on network effects to achieve scale, but these decay rapidly as new platforms emerge, therefore increasing business risk and then cost of capital (Ali et al., 2017). Additionally, larger firms in the Technology sector face greater regulatory scrutiny and risks of unfavourable policy shifts, especially related to privacy and market power, which raises their cost of capital (Freij, 2022).

The association between financial leverage and cost of capital was found, as expected to be positive, regardless of the type of capital or firms' systematic risk. This result confirms one of the fundamental relationships in finance, i.e., that more indebted business face higher financial risks, which are reflected into the costs they pay to access funds

(Modigliani & Miller, 1968; Brigham & Gordon, 1968), widely confirmed by empirical studies conducted on firms from different regions, industries and going through multiple stages of economic cycles—see, for example, the comprehensive reviews of Jagannathan et al. (2017).

Last, but not least, we used the Management score of LSEG-Refinitiv to moderate the relationship between costs of capital and sustainability practices in the Technology sector, as this indicator captures management's commitment towards sustainability and its efficiency in this respect. The results indicate higher managerial attention and dedication towards sustainable projects is reflected in lower costs of equity and WACC. This also means that investors are interested in the quality of managerial conduct in relation to sustainability and discount the financing costs in recognition of heightened commitment to sustainability. Several studies confirm our findings. For example, Duong et al. (2023) find that investors associate efficient carbon risk management with reductions in the probability of default, which is associated with lower costs of capital. Also, Sharfman and Fernando (2008) demonstrate that good environmental management is reflected in lower levels of the cost of capital, further confirmed by Benlemlih and Cai (2020).

The results presented in Tables 5 to 10 collectively demonstrate a strong persistence in Technology companies' cost of capital overtime, regardless of the type of cost of capital or panel of companies, as revealed by the positive and statistically significant 1-year lagged coefficients. This aligns with the path dependence of financing costs, whereby past financing decisions shape investors' perceptions and expectations on the risk-return trade-off and create path dependencies in the cost of capital that may prevent them from optimizing their capital structures (Kirch & Terra, 2019; Lemmon et al., 2008). For example, a firm that previously issued mostly equity may find it costlier to switch to debt financing due to signalling effects that could negatively impact stock price. Conversely, a heavily debt-financed firm may find equity issuances more costly due to the investors' perception that it is highly exposed to financial risks (Graham & Harvey, 2001). Moreover, although the theoretical calculation of WACC assumes that all financing sources are available to firms, regulations, investors' expectations, and past financing patterns can restrict companies' financing options.

Finally, all models are valid as indicated by the diagnostic tests. Our instruments possess validity, as evidenced by Hansen-Sargan test's p-value over the threshold of 0.05. Furthermore, the absence of serial correlation in residuals is confirmed, with an AR(2) test p-value surpassing 0.05. Hence, our estimations exhibit consistency and robustness.

5 Conclusions

Using ESG controversy data, this article provides compelling evidence on the financial materiality of sustainability greenwashing among corporations in the global Technology sector over an 8-year period. The granular analysis offers many intriguing findings with implications for actors in the Technology sector looking to incentivize truly sustainable transformation. First, increased overall sustainability controversies are associated with reduced equity financing costs, indicating that investors still value the development prospects of Technology corporations despite ethical concerns. Environmental conflicts, on the other hand, raise all types of financing costs. The findings show that, unlike shadowy social behaviour, the visibility of environmental externalities is sufficiently tangible that greenwashing environmental harms undermine value. As a result, Technology companies must demonstrate their environmental commitment through operational changes rather than surface behaviours. Furthermore, enterprises with reduced systemic risk suffer greater greenwashing penalties, demonstrating that resistance to disruption diminishes incentives to mislead. As a result, developing business models that address ethics as well as economics is financially advantageous. Meanwhile, higher-risk Technology firms maintain investor patience for greenwashing, but only for a limited time before scrutiny tightens.

It is clear from extant research and the current paper methodology and results that there are consistent implications of corporate greenwashing on financing cost, both cost of equity and debt. There implications are only likely to increase, as the direction of the policy and legislation leans towards more focus on sustainability. For instance, the European Union's "Fit for 55" legislative package will change the regulatory landscape for issuers of stocks and bonds and for public entities in general up until the year 2055. Also, the EU's Corporate Sustainability Reporting Directive 2022/2464, applicable as of 2023, obliges listed companies and large corporations to communicate publicly about the environmental impact of their activities. In this context, policymakers need tools to (i) measure ESG impact of companies (outside the scope of this paper) and (ii) understand and define scope of future regulations capable of steering companies in the right direction. In view of the latter objective, policymakers can use the results of this paper to address debt bias of companies and/or to incentivise sustainable behaviour (e.g. green financing policies, the EU green bond standard etc.).

Overall, the findings indicate that transparency is currently insufficient to protect against greenwashing in Technology industries, needing reforms in monitoring. Improved auditing and disclosure requirements would allow investors to price sustainability risk more appropriately. Furthermore, increasing the reputational costs of greenwashing through expanded environmental and social monitoring and reporting standards will better align financing costs with responsible transformation. The findings warn analysts against making hasty decisions about the materiality of sustainability commitments by substantiating greenwashing's varying implications on Technology firm financing costs. Controversy data shows that in order to avoid value destruction, technology providers must credibly portray environmental progress. As a result, managers should invest proactively in sustainability reforms to avoid reputation hazards, enable premium valuation, and keep operating licenses in the face of mounting public challenges. ESG ratings are still quite controversial due to lack of consistency in measurement, but firms with strong behaviour should be incentivised, e.g. through green financing policies. Also, in the not so very distant future, investment funds will have clear ESG investment policies that will exclude from the realm of investment certain industries or sectors. When it comes to Technology for instance, companies that rely heavily on data mining (which requires significant computer power and consumes heavily on fossil fuel energy) are already excluded from the investment horizon. Likewise, companies that lack robust governance or even board diversity may be excluded from the investments. Many countries already have compulsory diversity quotas for boards. Finally, multiple transparency mechanisms and coordinated governmental responses are required to realize sustainability in technological supply chains and business models that produce the breakthroughs that shape society's future.

However, certain limitations point to additional research avenues. Because the analysis is based on secondary datasets that lack business context behind specific controversies, surveys or interviews could help to enrich interpretation. Meanwhile, using Refinitiv classifications for technology companies simplifies sectoral diversity—for example, comparing software producers to hardware manufacturers may reveal variability within the Technology sector. Similar variability may be also identified when considering the origin countries of these firms. Finally, future research might include metrics like as carbon intensity alongside controversies data to provide a more comprehensive picture of the relationship between sustainability, greenwashing, and company financing costs.

Declarations

Data availability statement The data that support the findings of this study are available from the LSEG-Refinitiv platform, with access provided by the "Lucian Blaga" University of Sibiu, but restrictions apply to the availability of these data, which were used under licence for this study and so are not publicly available. The data are, however, available from the authors upon reasonable request and with the permission of the "Lucian Blaga" University of Sibiu.

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