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Do corporate carbon emissions affect risk and capital costs?

Adam G. Arian *, John Sands

Peter Faber Business School, Australian Catholic University, Banyo, Brisbane, QLD, 4014, Australia

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ABSTRACT

This study explores the impact of corporate carbon emissions on idiosyncratic risk and capital costs. Leveraging a dataset comprising 1016 company-year observations from Australian-listed companies over the period 2007 to 2020, our panel regression analysis reveals significant associations. We find that companies with higher carbon emissions experience elevated idiosyncratic risk, contributing to increased capital costs in both debt and equity markets. Our results remain robust after using alternative model specifications, accounting for the diverse nature of corporate carbon performance among industries, shaped by unique industrial factors. These results highlight the significance of carbon emissions pricing within financial markets and emphasize the importance of standardized corporate carbon disclosure in enhancing market efficiency, facilitating more accurate valuation, and guiding resource allocation in the broader economy.

1. Introduction

Climate change-induced extreme weather events, such as floods and droughts, pose significant ecological, health, and economic risks (Busch & Lewandowski, 2018). The transition to a low-carbon economy necessitates collaboration among stakeholders, and financial markets have grown increasingly aware of the financial implications of carbon-related issues due to demands for corporate environmental responsibility (Jung et al., 2018; Lee & Choi, 2021). While prior research supports the value-relevance of corporate carbon emissions performance information, its impact on a company's idiosyncratic risk has received limited attention. Examining how capital markets price the risks associated with corporate carbon emissions performance is essential, given their influence over companies based on their carbon performance. These insights empower companies to adapt their carbon management strategies, potentially reducing their idiosyncratic risk and overall cost of capital (COC).

Our study is motivated by the ongoing debate surrounding corporate environmental performance disclosure's role in shaping a firm's idiosyncratic risk. While some research supports this view (Arian & Sands, 2023; Clarkson et al., 2020; Gholami et al., 2023), there remains contention regarding the direct impact of corporate carbon emissions on idiosyncratic risk, as noted by Jung et al. (2018) and Millar et al. (2018). Specifically, our study posits that changes in corporate carbon emissions performance can influence stakeholders' perceptions of environmental risk and regulatory compliance, thereby impacting the company's exposure to idiosyncratic risk and its overall COC. Additionally, we address the ambiguity concerning the extent to which capital markets integrate corporate carbon emissions performance into lending and investment decisions (Cooper et al., 2018; Houqe et al., 2020; Marrone et al., 2020). Addressing these concerns, this study aims to highlight the relationship between corporate carbon emissions performance and idiosyncratic risk, bridging the gap in current knowledge (Jo & Na, 2012; Marrone et al., 2020).

* Corresponding author.
E-mail addresses: adam.arian@acu.edu.au (A.G. Arian), John.Sands@usq.edu.au (J. Sands).

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Idiosyncratic risk, a determinant of significant valuation fluctuations in companies (Bassen et al., 2006), carries substantial weight in the financial market. Managers are encouraged to develop strategies addressing the link between carbon emissions performance and company-specific risks, spanning physical, operational, regulatory, and stakeholder domains (Merton, 1987). Recognizing this connection, Jo and Harjoto (2011) argue that corporate endeavors aimed at reducing idiosyncratic risk can lead to more cost-effective access to financial resources. While some studies have explored the relationship between corporate carbon emissions performance and the COC (Clarkson et al., 2013; Clinch, 2013; Jung et al., 2018), a consensus remains elusive, leaving this association ambiguous (Trinks et al., 2020).

Our study also extends its focus to Australian companies, an area with limited research on the association between carbon emissions, idiosyncratic risk, and financial implications, in contrast to studies primarily cantered on U.S. and U.K. firms. Investigating how corporate carbon emissions performance influences the capital market, even in a context without explicit carbon costs, underscores the study's significance for corporate decision-making. Given that most listed companies acquire financial resources from both debt and equity markets, our comprehensive approach evaluates the economic implications of corporate carbon emissions performance using the weighted average cost of capital (WACC) as a benchmark. This approach addresses limitations in previous research and facilitates a more holistic understanding of the link between corporate carbon performance, emissions intensity, and COC (Aldamen & Duncan, 2013; Jung et al., 2018).

This study employs a 14-year dataset from 2007 to 2020, capturing evolving trends in the relationship between corporate carbon emissions performance, idiosyncratic risk, and the COC. Unlike previous research that often focused on single-year snapshots (Chapple et al., 2013; He et al., 2013), our extended timeframe provides a comprehensive view. We also examine various industry sectors, enhancing our understanding of complex interactions often overlooked in narrower sector-specific studies (Clarkson et al., 2008; Li et al., 2014). Our study, which includes 1016 company-year observations, validates both hypotheses. We further conduct tests to address potential systematic variations in idiosyncratic risk and COC levels that could lead to misleading correlations. The results reveal a positive relationship between corporate carbon emissions performance and idiosyncratic risk, indicating that lower carbon emissions performance is linked to reduced company-specific risk. Additionally, higher carbon emissions performance is associated with an increased COC, indicating that the capital market considers carbon emissions when assessing risk and determining capital costs. Each additional metric ton of carbon emissions results in an average 18.5% higher COC, underscoring the financial implications of carbon emissions. These findings emphasize the importance of carbon emissions management for risk mitigation and optimal financing choices. Our study's findings remain consistent across various industry- and year-specific sensitivity analyses, as well as tests that assess endogeneity concerns.

This study makes significant contributions to the existing literature in several keyways. Firstly, it addresses the pressing need for further research into the relationship between corporate carbon emissions and financial risks and capital costs, as topic highlighted by recent calls for investigation (Busch & Lewandowski, 2018; Lee, Min, & Yook, 2015; Wang et al., 2014). Secondly, our research diverges from prior studies (Fujii et al., 2013; Ganda, 2018) by examining the relationship between corporate carbon emissions and COC over an extended time frame, spanning from 2007 to 2020. This extended temporal scope is particularly significant because corporate environmental performance is regarded as a strategic investment. Investigating this relationship over a longer duration provides a more comprehensive and meaningful perspective on the relationship, shedding light on the strategic implications of carbon emissions. Lastly, the findings support the implementation of standardized reporting mechanisms, which not only improve market efficiency and resource allocation but also play a pivotal role in advancing financial accounting frameworks for recognizing and reporting carbon emissions. These advancements, in turn, facilitate future research efforts in this domain (He et al., 2021; Warwick & Ng, 2012).

The remainder of this paper is structured as follows. Section 2 discusses Australian carbon legislation. Section 3 presents the relevant theory and literature on corporate carbon emissions, followed by the development of the study's two hypotheses. Section 4 discusses the study's data, sample selection and variables, and estimation models. The results are presented in Section 5, and the paper concludes with Section 6.

2. Australian carbon emissions legislation

The landscape of climate change and carbon emissions regulation has rapidly evolved, significantly impacting the relevance and practical implications of our study. As nations worldwide grapple with the challenges posed by carbon emissions, regulations have emerged as crucial instruments for mitigating environmental risks and fostering responsible business practices (Bebbington & Larrinaga-Gonzalez, 2008; Labatt & White, 2011). The imperative for a socially responsible approach to resource allocation has spurred debates within the capital market domain (Gutiérrez-Nieto et al., 2016), compelling corporations to confront the dual challenge of maximizing profits while addressing environmental concerns (Linnenluecke et al., 2020).

In Australia, the National Greenhouse and Energy Reporting Act 2007 (NGER Act) plays a pivotal role in shaping corporate carbon emissions disclosure regulations. Administered by the Clean Energy Regulator, this act mandates businesses surpassing specific emission thresholds to register and report their carbon emissions, energy consumption, and production. This transparent disclosure framework provides stakeholders with critical insights into the carbon footprint of registered businesses, thereby fostering accountability and informed decision-making. Additionally, the landmark 'Securing a Clean Energy Future' plan introduced by the Australian Government in 2011 has galvanized companies towards significant social and economic commitments (Subramaniam et al., 2015). This plan underscores the profound transformation within the business landscape, where managing carbon emissions risks and embracing sustainable practices have become imperative for strategic resilience.

By exploring the relationship between corporate carbon emissions performance, idiosyncratic risk, and financial outcomes, we directly engage with the contemporary discourse on environmental sustainability and corporate responsibility. Moreover, our findings contribute to the practical understanding of how businesses navigate these evolving regulations, adapting their strategies to align with changing market dynamics.

3. Theoretical framework and hypotheses development

The theoretical framework, based on stakeholder theory, highlights the significance of creating value for various stakeholders by aligning interests. Stakeholder pressure for carbon emissions performance disclosure is intimately tied to the value creation concept and necessitates alignment with corporate strategic decision-making (Freeman et al., 2010). This framework emphasizes that effective corporate strategies should be responsive to stakeholders' concerns and harmonize corporate objectives with available resources (Deegan, 2014). On the other hand, companies use disclosure to elaborate on their environmental performance. Therefore, they will be rewarded with more investment from the equity market, higher consumer trust, higher employee productivity, and stakeholders' support (Richardson et al., 1999).

Furthermore, the adoption of carbon emissions regulations has thrust carbon risk management into a prominent role as a business strategy (Clarkson et al., 2015). The uncertainty associated with future carbon emissions regulations introduces complexity into a company's exposure to carbon emissions, leading to uncertainties in future cash flows, earnings, and brand reputation (Chen & Gao, 2012; Labatt & White, 2011; Schneider, 2011; Sharfman & Fernando, 2008). Research has indicated a positive connection between corporate carbon performance and a firm's total and idiosyncratic risk (Bouslah et al., 2013). It is essential to recognize that carbon performance disclosure and environmental reporting mechanisms come with associated costs, which can be seen as an additional operational risk (Cormier & Magnan, 2015; Peters & Romi, 2014). Moreover, the relationship between voluntary disclosure and actual performance is intricate; not all voluntary disclosures necessarily equate to positive environmental performance (Cahan et al., 2015; Carey et al., 2017; Clarkson et al., 2008, 2011). Managers might strategically over-disclose information or use disclosure as a symbolic gesture to appear environmentally conscious (Clarkson et al., 2013), indicating that environmental disclosure's efficiency might vary substantially. Regulations governing environmental performance disclosure further have the potential to impact company-specific risks. Depending on stakeholder perceptions, corporate carbon emissions performance disclosure could either mitigate idiosyncratic risk if perceived positively or exacerbate it if met with concerns (Brown & Deegan, 1998; Lee, Min, & Yook, 2015). This nuanced interplay highlights the intricate relationship between corporate carbon emissions performance, disclosure, and idiosyncratic risk. By delving into these dynamics, the study aims to contribute to a more comprehensive understanding of how carbon emissions performance intersects with corporate risk profiles.

Investigating the impact of corporate carbon emissions performance on the different aspects of company risk is an important yet under-researched area in the accounting and finance literature (Tzouvanas et al., 2020). Some studies in the literature predict that corporate environmental performance disclosure would improve information asymmetries and reduce idiosyncratic risks (Ferguson & Lam, 2021; Goh et al., 2016; Gul et al., 2020). Gaspar and Massa (2006) argue that companies that include environmental responsibility in their operating strategy can construct a solid relationship with stakeholders, thereby lowering idiosyncratic risk. Poddi and Vergalli (2009) use systematic risk (beta) from the capital asset pricing model (CAPM) as a proxy for company risk and investigate the impact of corporate environmental performance disclosure on a company's systematic risk. They find that corporate environmental performance disclosure can effectively minimise systematic risk. Salama et al. (2011) and Oikonomou et al. (2012) find a moderate negative association between the level of environmental performance disclosure and idiosyncratic risk. This is consistent with Jo and Na (2012), who argue that companies use environmental disclosure for risk management purposes. Jiang et al. (2009) argue that a corporate carbon emissions performance disclosure improves idiosyncratic risk and commits a company to its carbon emissions reduction plan. However, such a mechanism could be detrimental as it exposes companies to potential criticism and costs related to pollution abatement (Lee, Min, & Yook, 2015). Corporate carbon emissions performance disclosure can negatively impact investors concerned about the 'green' future and related investment strategies (Cormier & Magnan, 2015). In contrast to the extant literature investigating the impact of corporate environmental performance on financial performance or systematic risk, studies concentrating on the direct impact of corporate carbon emissions performance disclosure on idiosyncratic risk are limited (Benlemlih & Girerd-Potin, 2018; Cooper et al., 2018; Jo & Na, 2012). The current study examines how corporate carbon emissions performance affects company risk, focusing on idiosyncratic risk. Therefore, the recommended first hypothesis of this study is as follows:

H1. There is a positive association between corporate carbon emissions performance and idiosyncratic risk.

Theoretical considerations for the second hypothesis underscore that a company's extensive carbon emissions performance and associated risks could elevate its default risk within the context of the capital market. Elevated carbon emissions often entail increased compliance costs, diminished profitability, and impaired cash flows (Subramaniam et al., 2015; Weber, 2012). Companies with subpar environmental practices are vulnerable to brand damage, operational disruptions, loss of market competitiveness, and adverse impacts on future cash flows (Labatt & White, 2011). The importance of incorporating corporate carbon emissions performance into risk assessments for investment decisions is emphasized (Matsumura et al., 2014). Financial institutions face the prospect of additional regulatory and reputational risks tied to carbon-related projects (Li et al., 2014; Wegener et al., 2013). Consequently, the ability of lenders to attract customers and generate revenue streams might be compromised due to potential damage stemming from carbon emissions (Subramaniam et al., 2015; Thompson, 1998; Weber, 2012). Research also suggests that financial institutions apply a higher risk premium to carbon-polluting companies with elevated carbon emissions (Kim et al., 2015). Credit rating agencies are known to downgrade firms with higher carbon emissions (Li et al., 2014; Matsumura et al., 2014). Considering heightened regulations and public concerns surrounding corporate carbon emissions performance, evidence indicates that capital markets have integrated associated risks into their financing operations. This integration is facilitated by policies designed to manage carbon emissions exposures and align financing activities with evolving environmental considerations.

Prior research studies largely concentrate on corporate environmental performance and the impacts of related risks on a company's COC, with little focus narrowly on corporate carbon emissions performance (Bui et al., 2020; Clarkson et al., 2013; Jung et al., 2018; Maaloul, 2018; Sharfman & Fernando, 2008). Sharfman and Fernando (2008) report a positive association between a particular environmental risk measure and COD across a sample of United States (US) companies. Clarkson et al. (2013) find no relationship between corporate environmental performance and COE but a positive and significant association between poor environmental performance and cost of equity (COE). In a study on Canadian-listed companies, Maaloul (2018) finds corporate carbon emissions increase COD by an average of 11–15%. Jung et al. (2018) find a positive relationship between a corporate carbon risk awareness measure and cost of debt (COD). More recently, in a multinational study by Bui et al. (2020), corporate carbon emissions performance find to be positively associated with the cost of equity (COE). However, as it is argued by Aldamen and Duncan (2013), investigating the economic impact of corporate carbon emissions performance exclusively from the equity or debt market cannot provide a complete resolution.

Prior studies on the relationship have created an extensive debate amongst academics and practitioners to investigate how corporate carbon emissions performance helps to improve energy efficiency and minimise the cost to the economy. The emissions reduction legislation may lead to higher financial costs and related risks for companies that fail to improve their carbon emissions performance. This study argues that the significant impact of carbon emissions performance initiatives and regulations on businesses should be clearly understood, even though mitigating their risks and financial impacts are hard. This study posits that higher corporate carbon emissions performance results in having higher COC in the capital markets, including debt and equity markets. Therefore, the second hypothesis of this study is:

H2. *There is a positive association between corporate carbon emissions and the overall cost of capital (COC).*

4. Research design

4.1. Empirical models

In this section, the empirical models to analyse the hypotheses of this study are provided. As with the studies by Mishra and Modi (2013) and Benlemlih (2017), this study calculates and uses various company's risk measures, including systematic and idiosyncratic risks, to examine the first hypothesis (H1). This study also follows prior literature (Benlemlih, 2017; Benlemlih et al., 2018; Gholami, et al., 2022; Maaloul, 2018) and includes other financial determinants impacting a company's financial operation. To be specific, these measures include: the company's bankruptcy risk or default risk (*Z_Score*); systematic risk (*Beta*); company profitability (*ROA*); company market price to book value (*M/B*); company size measured by the natural logarithm of total assets (*LNTA*); debt ratio (*LEV*) measured by total liabilities divided by total assets; the ratio of property, plant and equipment to total revenue (*PPE*); capital expenditure ratio (*CAPEX*) measured by capital expenditure divided by total revenue; revenue growth (*GROWTH*) measured by the revenue percentage change between the periods; and cash ratio (*CASH*) measured by the item 'cash' divided by total assets.

This study proposes that corporate carbon emissions positively impact idiosyncratic risk. Therefore, the following equation is estimated:

$$Idio\_Risk_{i,t} = \beta_0 + \beta_1 GHG_{i,t} + \beta_2 Control_{i,t} + IndustryFixedEffect_t + YearFixedEffect_t + \varepsilon_{it} \quad (1)$$

The current study expects companies with higher carbon emissions to have higher credit- or investment-related risks and tolerate a higher interest rate. Consistent with these expectations, this study regresses corporate COC on carbon emissions to examine the second hypothesis (H2).

$$COC_{i,t} = \beta_0 + \beta_1 GHG_{i,t} + \beta_2 Control_{i,t} + IndustryFixedEffect_t + YearFixedEffect_t + \varepsilon_{it} \quad (2)$$

4.2. Control variables

Following prior literature (Chen et al., 2017; McLean et al., 2012), we consider a set of control variables to enhance our understanding of the relationship between corporate carbon emissions performance and the factors under investigation. We incorporate a diverse set of control variables that capture various dimensions of firm performance and financial characteristics. We consider the following control variables in our analysis: *Z_Score*, employed as a proxy for financial constraint, allows us to assess the financial health and stability of firms. Beta, used as a measure of systematic risk, provides valuable insights into how a firm's stock price responds to changes in the market. Return on Assets (*ROA*) is utilized to gauge the efficiency and profitability of a firm's operational activities. Market-to-Book Ratio (*M/B*) reflects the market's valuation of a firm relative to its book value. The Natural Logarithm of Total Assets (*LNTA*) enables comparisons among entities of varying scales by representing firm size. Leverage (*LEV*) indicates a firm's degree of financial leverage through the ratio of total liabilities to total assets. The Ratio of Tangible Fixed Assets to Total Assets (*PPE*) provides insights into the proportion of tangible assets within a firm's total assets. Capital Expenditure (*CAPEX*) offers information about a firm's investments in future growth and expansion. Growth (*GROWTH*) measures the firm's rate of expansion over a specific period, reflecting its growth trajectory. Lastly, Cash to Total Assets (*CASH*) signifies the proportion of liquid assets within a firm's total assets.

4.3. Data and sample selection

This study obtains the corporate carbon emissions (or GHG emissions) data and all accounting variables from the Bloomberg database. The initial sample includes all Australian-listed companies from 2007 to 2020 (1161 company-year observations). The companies with missing data are excluded from this study's sample. This results in the final sample of 1016 company-year observations, as presented in Table 1.

The Australian carbon emissions performance reporting regulations were defined under the NGER act in 2007. The study period starts from the inception of the NGER act in 2007 as a major economic and environmental reform that could change the business environment. The NGER Act and further climate change plan named 'Securing a Clean Energy Future' in 2011 target reducing pollution by 5 per cent by 2020.

Table 2 presents the sample distribution by industry sector, in which the financial, basic materials and consumer non-cyclical sectors comprise the largest proportions (25%, 21% and 15%, respectively). The technology, communications and utility sectors comprise the smallest proportions (1%, 3% and 3%, respectively). Due to missing carbon information, the current study excludes the health care sector. The industry classifications are based on the Bloomberg Industry Classification System (BICS).

4.4. Measurement of variables

4.4.1. Corporate carbon emissions

This study uses Bloomberg's carbon emissions data frequently used in prior literature (Matsumura et al., 2014; Sharfman & Fernando, 2008). Bloomberg reports total carbon emissions as the total of the company's direct emissions (Scope 1) and all indirect emissions (Scope 2).

This study further follows previous literature (Bui et al., 2020; Maaloul, 2018; Matsumura et al., 2014) and measures carbon emissions in two ways: total carbon emissions and carbon emissions intensity. This negates any concerns about the comparability of carbon emissions between different industries. Total corporate carbon emissions are measured based on the total amount of scope from all company sources and scope two from a company's electricity, heat or steam consumption. The carbon emissions intensity is a ratio of total corporate carbon emissions scaled by total revenue. This ratio helps mitigate the impact of extreme variance across different sectors, so data becomes more comparable across different reporting periods (Kim et al., 2015; Luo & Tang, 2014; Wegener et al., 2013).

4.4.2. Idiosyncratic risk

Most of the uncertainty and volatility of a particular asset over time are caused by idiosyncratic risk. Idiosyncratic risks include diverse elements, such as a company's investment strategies, management decisions, financial policies and procedures, its operation's geographic location, and even corporate culture. Richardson (2009) argues that corporate environmental performance elements, such as carbon emissions, resource scarcity, actions limiting a company's monetary policy or increases in its cost of capital, are essential in different economic situations. Therefore, incorporating corporate environmental performance into credit risk assessment and investment evaluation is critical in a long-term corporate strategy setting (Richardson, 2009).

The current study considers various company's risks, such as systematic and idiosyncratic risks, to examine the impact of corporate carbon emissions on idiosyncratic risks. The study follows Mishra and Modi (2013) and Benlemlih (2017) to calculate the company's idiosyncratic risk according to total risk. Total risk includes market risk (beta) and company-specific (idiosyncratic) risk. The total risk is traditionally measured by the market return variance, or typically standard deviation (Brealey et al., 2001). The market risk provided by the Bloomberg database is calculated based on beta in the capital asset pricing model (CAPM) associated with the market

Table 1
Data selection process.

Year	Data availability in GHG samples	Missing data	Total available observations
2007	44	1	43
2008	55	3	52
2009	58	5	53
2010	68	4	60
2011	65	5	64
2012	73	5	68
2013	79	5	74
2014	82	6	74
2015	92	6	86
2016	93	6	87
2017	92	7	87
2018	118	35	85
2019	119	30	89
2020	123	29	94
Total	1161	147	1016

This table presents the selection of data across all listed companies.
GHG: greenhouse gas/es.

Table 2
Sample composition by sectors.

Year	Observations	%
Basic materials	211	21%
Communications	31	3%
Consumer cyclical	87	9%
Consumer non-cyclical	152	15%
Energy	99	10%
Financial	254	25%
Industrial	137	14%
Technology	10	1%
Utilities	35	3%
Total	1016	100%

This table illustrates the distribution of our sample across different industry specifications. The industry categorization follows the Bloomberg Industry Classification System (BICS).

return. Beta represents the systematic risk of a company relative to the market risk in general. The current study calculates idiosyncratic risk based on the market beta provided by the Bloomberg database.

4.4.3. Cost of capital (COC)

Most publicly listed companies source their financial needs through debt and equity capital. In the equity market, the COE is the investors' required rate of return after including a company's particular risks. Investors use this to measure discounted future cash flow generation for companies. A higher required rate of return means higher financial costs for the company in sourcing its financial needs through the equity market. COD is the cost of borrowing financial resources from sources other than the equity market, which is the debt market. Resource providers in the debt market include banks, private institutions or institutional investors, and other financial institutions. These financing options may lead to company interest costs (Sharfman & Fernando, 2008). Therefore, a company's overall COC should include the debt and equity market costs. The weighted average cost of capital (WACC) provides the average cost of financing, including the COD and COE. Following Sharfman and Fernando (2008), the WACC (named COC) is used in this study. This study obtained data from the Bloomberg database. Details of the WACC calculation by the Bloomberg database are presented in Appendix A.

5. Empirical results

5.1. Descriptive statistics

Table 3 presents descriptive statistics for the variables of this study. This study winsorises the variables at 1% and 99% levels to control the impact of outliers. The mean value of the WACC is 8.58, with values ranging from 1.45 to 25.04, which includes interest rates in both equity and debt markets. The mean value of idiosyncratic risk (Idio_Risk) is 3.08, with values ranging from 1.25 to 5.07, representing the company-specific risk for companies in the study's sample. The mean carbon emissions are 2831 metric tons, significantly larger than the median at 192.94 metric tons. The mean of carbon emissions intensity (*GHG_INT*) is 0.437. This indicates that, on average, Australian companies emit 0.437 tons of carbon per million dollars of revenue, a result consistent with prior studies in

Table 3
Summary statistics.

Variables	Mean	Median	Standard deviation	Minimum	Maximum
WACC	8.5817	7.9648	3.1956	1.4569	25.064
Idio_Risk	3.0831	3.0604	0.5571	1.2582	5.0751
GHG	2831.6	192.94	8089.1	0.0064	62,600
GHG_INT	0.4371	0.1094	1.3533	0.0005	35,103
Z_Score	2.0063	1.7497	1.5753	−2.6603	8.4117
Beta	0.7559	0.7873	1.2042	−38.127	4.8355
ROA	4.1357	4.2095	10.040	−90.508	113.27
M/B	3.9811	1.5471	27.476	0.0041	2094.3
LNTA	8.7969	8.7418	1.7339	2.1563	13.791
LEV	0.5068	0.4781	0.2077	0	0.9945
PPE	4.8577	4.6114	2.2996	0.8452	11.189
CAPEX	2.1027	2.0655	1.3923	2.8172	5.7697
GROWTH	2.2443	2.2776	1.2156	2.3953	7.7473
CASH	5.3356	2.4091	7.8432	0.0117	79.915

This table provides descriptive statistics for the study's key variables: GHG (Greenhouse Gas Emissions), GHG_INT (Emissions Intensity), WACC (Weighted Average Cost of Capital), and Idio_risk (Idiosyncratic Risk). It also includes other company characteristics such as Z_Score, Beta, ROA (Return on Assets), M/B (Market to Book Value), LNTA (Total Assets), LEV (Total Debts Ratio), PPE (Property, Plant, and Equipment), CAPEX (Capital Expenditure), GROWTH (Revenue Growth), and CASH (Cash).

the same geographic region (Li et al., 2014). The mean value of other control variables such as the default risk (*Z_Score*); systematic risk (*Beta*); profitability (*ROA*); market to book value (*M/B*); company size (*LNTA*); leverage (*LEV*); property, plant, and equipment (*PPE*); capital expenditure (*CAPEX*); revenue growth (*GROWTH*); and liquidity (*CASH*) are all comparable with prior studies (Goss & Roberts, 2011; Griffin et al., 2017).

It is also crucial to evaluate the impact of industry membership as a valid control variable in this study, as recommended by prior literature (Gebhardt et al., 2001; Sharfman & Fernando, 2008). Companies in different industries have a systematically different levels of environmental risks and COC, resulting in a spurious correlation between idiosyncratic risk and cost of capital (COC). This study follows Sharfman and Fernando (2008) and Maaloul (2018) to address this issue by treating the industry impact as an empirical one, thus determining whether this affects companies in the sample. This study performs the analysis of variance (*ANOVA*) with COC as the dependent variable and corporate carbon emissions and emissions intensity as the independent variables.

Table 4 presents descriptive statistics by industry and ANOVA results across industry sectors. The results indicate a significant difference at 1% significance level between industry sectors concerning carbon emissions (ANOVA = 20.72 and 10.12) and cost of capital (COC) (ANOVA = 24.77). As shown in Table 4, the utilities sector is ranked first in carbon emissions and COC, followed by the basic material, consumer cyclical and energy sectors.

Table 5 presents Pearson's correlation coefficients for the study's variables. The results show that the correlation between idiosyncratic risk and the two measures of carbon emissions (total carbon emissions and carbon emissions intensity) is positive and statistically significant at the 1% level (0.1176 and 0.2666). Furthermore, the results show a positive association between the WACC and corporate carbon emissions (0.1799 and 0.2673). These results support both hypotheses and suggest that the capital markets consider corporate carbon emissions in their investment and lending decisions. This also suggests that equity and debt markets consider corporate carbon emissions in their investment and lending decisions. Companies with higher carbon emissions face higher risk and higher COC.

As shown in Table 5, idiosyncratic risk and the WACC are negatively and significantly correlated with LNTA, LEVERAGE, Beta, ROA and M/B, consistent with prior studies (Goss & Roberts, 2011; Li et al., 2014; Maaloul, 2018). Other variables, such as PPE, CAPEX, revenue growth (*GROWTH*) and liquidity (*CASH*), are positively and significantly correlated with idiosyncratic risk and the WACC, which is also consistent with the findings of prior studies (Bui et al., 2020; Li et al., 2014). Finally, as shown in Table 5, correlations between the variables are below the critical value of 0.7, indicating that multicollinearity is not an issue (Cohen et al., 2013; Hair et al., 2006).

5.2. Main regression results

5.2.1. Corporate carbon emissions and idiosyncratic risk

Columns (1) and (2) in Table 6 present the results of our analysis, focusing on the connection between corporate carbon emissions and idiosyncratic risk. Notably, the coefficients for corporate carbon emissions in both cases are found to be positive and statistically significant ($\beta = 1.2128$, $p < 0.01$; $\beta = 1.3269$, $p < 0.10$). This critical finding suggests a compelling link between higher levels of carbon emissions and increased idiosyncratic risk within companies. In essence, companies with greater carbon emissions are shown to be exposed to higher levels of company-specific risk, aligning with previous research findings (Benlemlih et al., 2018; Cai et al., 2016). This insight underscores the importance of considering carbon emissions performance as a significant factor impacting idiosyncratic risk, thereby emphasizing the relevance of our study within the broader context of corporate risk management and sustainability practices.

Across all other control variables, systematic risk (*Beta*), return on assets (*ROA*), market to book value (*M/B*), and company size (*LNTA*) show a negative association with idiosyncratic risk at a 1% statistical significance level. This is consistent with prior literature that finds that companies with larger assets diversify their operations; therefore, they have lower idiosyncratic risk (Benlemlih et al., 2018; Tzouvanas et al., 2020). Larger companies attract more stakeholder attention (Bansal, 2005). Therefore, they manage their environmental performance better, resulting in less idiosyncratic risk (Gebhardt et al., 2001). Similarly, companies with higher capital expenditure (*CAPEX*) are likely to have lower idiosyncratic risk.

Table 4
Sector-wise descriptive statistics and ANOVA analysis.

Sector	Aggregate GHG Emissions (metric tons)		Carbon Emissions Intensity (%)		Cost of capital (COC) (%)	
	Mean	Rank	Mean	Rank	Mean	Rank
Utilities	10,319.22	1	249.79	1	11.74	1
Basic materials	8093.43	2	66.95	3	9.45	3
Consumer cyclical	2583.45	3	30.46	5	8.55	6
Energy	2483.32	4	90.76	2	10.61	2
Industrial	1132.78	5	33.13	4	8.61	5
Consumer non-cyclical	843.37	6	16.48	7	8.31	7
Communications	589.02	7	17.13	6	9.31	4
Financial	202.12	8	6.54	8	7.86	9
Technology	17.16	9	0.96	9	8.03	8
ANOVA	20.72***		10.12***		24.77***	

This table displays descriptive statistics categorized by industry sectors and includes an analysis of variance (ANOVA) conducted across these sectors.

Table 5
Correlation matrix.

Statistics	Idio_risk	WACC	GHG	GHG_INT	Z_score	Beta	ROA	M/B	LNTA	LEV	PPE	CAPEX	GROWTH	CASH
Idio_Risk	1													
WACC	0.3039***	1												
GHG	0.0978***	0.2877***	1											
GHG_INT	0.1537***	0.3625***	0.3112***	1										
Z_Score	0.0710***	0.1245***	0.1278	−0.2104***	1									
Beta	−0.2322***	0.3212***	0.3718***	0.1601	0.0577***	1								
ROA	−0.1516***	0.1274	−0.2606	−0.2641	0.0564***	−0.1258***	1							
M/B	−0.3211***	−0.1241***	−0.2401	−0.2918***	0.1632***	0.0807***	0.3224***	1						
LNTA	−0.1789***	0.0318***	−0.2204	0.3785***	0.2415	0.2192***	−0.2702***	0.0466	1					
LEV	0.1420***	−0.0214***	−0.2505	−0.3842***	−0.3918***	0.0444	−0.2154***	0.1578***	0.1268***	1				
PPE	−0.2150***	−0.1012***	0.3914***	0.3265***	−0.3518***	−0.2401***	0.2368	−0.2004***	−0.1548***	−0.3645***	1			
CAPEX	−0.1216***	0.2179***	0.2442***	0.2574***	−0.0268***	−0.3172	0.0555	−0.3158	−0.0789***	−0.3978***	0.2156***	1		
GROWTH	0.2152***	0.0618***	0.2618	0.2147***	0.2135	0.2697***	0.1958***	0.0718	−0.0466	−0.1289***	0.1822***	0.2144***	1	
CASH	0.3271***	0.2891***	−0.1147	0.0455***	0.3564	−0.0558***	0.1228***	0.1155***	−0.3612***	−0.0456***	−0.0544	0.3164	0.0785***	1

This table presents Pearson correlation coefficients for the variables analysed in this study over the period from 2007 to 2020. Significance levels are denoted by superscript asterisks: ***, **, and * correspond to 1%, 5%, and 10% significance levels, respectively.

Table 6
Regression analysis.

Variables	Risk	
	(1)	(2)
GHG	1.2128***	
	(0.2781)	
GHG_INT		1.3269***
		(0.3424)
Z_Score	2.8175***	2.9867***
	(0.6476)	(0.6560)
Beta	−3.9083**	−3.5674**
	(2.3627)	(2.3701)
ROA	−0.6423***	−0.6173***
	(0.0714)	(0.0737)
M/B	−0.2944***	−0.3035***
	(0.2329)	(0.2343)
LNTA	−4.7560***	−3.6262***
	(0.5487)	(0.4277)
LEVERAGE	2.3290*	3.1962**
	(3.9807)	(4.0498)
PPE	0.7273	0.2075
	(0.5888)	(0.5873)
CAPEX	0.3559	0.2763
	(0.6136)	(0.6210)
GROWTH	0.9008**	0.8045**
	(0.3684)	(0.3734)
CASH	0.2884***	0.2917***
	(0.0726)	(0.0732)
Constants	5.4402***	5.6194***
	(5.2378)	(5.5956)
Year Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observations	1016	1016
R-squared	0.4367	0.4304

This table displays regression results for idiosyncratic risk regressed on corporate GHG emissions and emissions intensity, along with control variables. Column (1) pertains to GHG emissions, while Column (2) relates to emissions intensity. Coefficient estimates and robust standard errors (in parentheses) are presented. Significance levels are indicated by superscript asterisks: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

On the other hand, companies with higher leverage (*LEV*) are riskier as they are exposed to a higher risk of default. Similarly, the higher the default risk (*Z_scores*), the higher the idiosyncratic risk. Finally, other control variables, including property, plant and equipment (*PPE*), revenue growth (*GROWTH*) and liquidity (*CASH*), are positively associated with idiosyncratic risk; however, they are not robust in the model's specification. Taken together, the results from the control variables are consistent to a considerable extent with relevant studies, including Benlemlih et al. (2018) and Jo and Na (2012) and Cai et al. (2016).

These results indicate that companies with higher carbon emissions face a higher idiosyncratic risk. In other words, investors and creditors impose a higher risk premium on companies with high carbon emissions when making financial resource allocation decisions. Therefore, the first hypothesis (H1) of this study is supported.

5.2.2. *Corporate carbon emissions and cost of capital (COC)*

Table 7 shows the results of the panel regression analysis of COC on carbon emissions (first columns) and emissions intensity (second columns), including other control variables. In the first set of columns, we observe a noteworthy positive association between corporate carbon emissions and COC, even when accounting for the influence of other variables that exert an impact on COC. This outcome signifies that higher corporate carbon emissions are linked to a heightened COC, suggesting that investors and lenders place a risk premium on companies with elevated carbon emissions levels, leading to an elevated COC. The coefficients, as presented in Table 7, range between 0.18 and 0.19 for both corporate carbon emissions and emissions intensity. Notably, this yields an average coefficient of 0.185, implying an average 18–19% surge in COC for each additional metric ton of carbon emissions. This figure essentially translates into a financial penalty imposed on the company, signifying the critical role that carbon emissions performance plays in the assessment of capital costs and financial risk. These findings accentuate the financial implications of corporate carbon emissions and further underline the relevance of our study within the realm of corporate finance and sustainability practices.

The COC has a statistically significant and positive association with the following control variables, namely the default risk (*Z_Score*), systematic risk (*Beta*), return on assets (*ROA*), market to book value (*M/B*), debt ratio (*LEV*), and revenue growth rate (*GROWTH*). This indicates that companies with a higher risk of default, higher systematic risk, higher profitability, higher market value, higher debt ratio and revenue growth rate have to pay the higher capital costs to raise capital. This is consistent with prior literature by Sharfman and Fernando (2008) and Bui et al. (2020). Overall, the results from all control variables are in line with prior

Table 7
Regression analysis.

Variables	Cost of Capital (COC)	
	(1)	(2)
GHG	0.1873***	
	(0.0675)	
GHG_INT		0.1981***
		(0.0828)
Z_Score	0.3602**	0.3846**
	(0.1570)	(0.1586)
Beta	2.8793***	2.9412***
	(0.5730)	(0.5732)
ROA	0.0318**	0.0352***
	(0.0173)	(0.0178)
M/B	−0.0363*	−0.0375*
	(0.0565)	(0.0567)
LNTA	−0.1270	−0.0499
	(0.1331)	(0.1034)
LEVERAGE	−2.0654*	−1.9474
	(0.9653)	(0.9794)
PPE	0.1976	0.1181
	(0.1428)	(0.1420)
CAPEX	−0.1563	−0.1731
	(0.1488)	(0.1502)
GROWTH	0.2376***	0.2238**
	(0.0893)	(0.0903)
CASH	0.0582***	0.0591***
	(0.0176)	(0.0177)
Constants	5.9674***	6.2002***
	(1.2702)	(1.3291)
Year Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observations	1016	1016
R-squared	0.2876	0.2835

This table displays regression results for cost of capital (COC) regressed on corporate GHG emissions and emissions intensity, along with control variables. Column (1) relates to GHG emissions, while Column (2) relates to emissions intensity. Coefficient estimates and robust standard errors (in parentheses) are presented. Significance levels are indicated by superscript asterisks: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

literature.

The findings support the study's second hypothesis (H2) that equity and debt markets include corporate carbon emissions in resource allocation evaluation. Companies with higher carbon emissions encounter a higher financial cost when sourcing their capital needs through the capital markets. The findings are consistent with prior studies by Jung et al. (2018); Sharfman and Fernando (2008), and Bui et al. (2020). The current study's findings align with the extant literature advocating that companies should meet environmental and ethical operational standards to become attractive to the capital market, providing them with cheaper financial support (Dhaliwal et al., 2011; Heinkel et al., 2001; Matsumura et al., 2014; Merton, 1987).

5.3. Robustness tests and endogeneity analyses

In this section, we delve into an examination of the robustness of our results, considering several critical factors. These factors include addressing the asymmetric nature of corporate carbon performance, accounting for endogeneity concerns, addressing heterogeneity, and exploring sensitivity to alternative estimation methods. Overall, these investigations provide substantial support for our primary finding, which highlights the positive relationship between corporate carbon emissions, idiosyncratic risk and capital costs.

5.3.1. Endogeneity analyses

In this section, we present additional analyses conducted to support our primary findings. According to Slack resource theory, an increase in access to lower-cost debt may potentially lead to an increase in corporate carbon emissions, but the precise direction of this relationship remains uncertain. To address the potential issue of simultaneous causality between the COC and corporate carbon emissions, we adopt a method employed in prior research (Busch & Hoffmann, 2011; Lewandowski, 2017; Trumpp & Guenther, 2017). Specifically, we introduce a lag of one and two years for the independent variables, relative to the cost of capital (COC). This lagging approach serves a dual purpose: it helps mitigate the impact of simultaneous causality and accounts for potential delays in carbon emissions disclosure, considering that maintaining corporate carbon emissions can yield financial benefits over the long term. The results from these lagged analyses reinforce our primary findings. We observe that the lagged values of the carbon emissions and its intensity exhibit a statistically significant positive association with corporate idiosyncratic risk and COD, indicating that endogeneity arising from simultaneous causality is not exerting a substantial influence on our primary result.

5.3.2. Sensitivity analyses

Due to the asymmetric nature of corporate carbon emissions across different industries, companies have different risk management strategies that reflect their operations, revenue, carbon intensity, and potential technological alternatives (Busch & Hoffmann, 2007). The current study includes extra sensitivity analysis undertaken to address the asymmetric nature of corporate carbon performance from high-emitting and low-emitting companies. The study follows previous literature (Bui et al., 2020; Jung et al., 2018), splitting companies in the sample based on the median carbon emissions intensity (*GHG_INT*) into high- and low-intensity companies and performing regression analysis. The results, presented in Table 8, are consistent with the findings of the main estimation models. The risks associated with companies' operations with high carbon emissions indicate that they may need to reconsider their borrowing capabilities. The capital market (including equity and debt markets) imposes a higher risk premium and, consequently, a higher interest rate based on the uncertainty related to corporate carbon emissions performance (Li et al., 2014; Maaloul, 2018).

5.3.3. Additional analyses-after dropping financial sector

Additionally, we recognize the significance of addressing the potential impact of the financial sector on our findings. Thus, following prior literature (Gholami et al., 2022; Gillan et al., 2021), we have excluded the financial sector from our analysis to address the unique characteristics of financial firms, particularly concerning financial measures like leverage. These sensitivity tests are being conducted separately, and it's noteworthy that the preliminary results align consistently with our primary findings, reaffirming the reliability and robustness of our conclusions. For the sake of brevity, we refrain from presenting the detailed results and tables in this section. Overall, the results remained consistent across a battery of sensitivity analyses, supporting the current study's hypotheses.

6. Conclusion

The main purpose of this study is to examine the impact of corporate carbon emissions performance on idiosyncratic risk and cost of capital (COC). It also estimates the average interest rate applied by the capital markets for corporate carbon emissions performance. Using a sample of 1016 company-year observations from 2007 to 2020 and controlling for industry and year-fixed effects, the results support the two hypotheses of the study. The study incorporates extra tests to address concerns about systematic differences in the level

Table 8
Sensitivity analysis – intensity level.

Variables	Risk		Cost of Capital (COC)	
	High intensity	Low intensity	High intensity	Low intensity
GHG	3.5748**	1.9818**	0.6293***	0.1473***
	(1.3584)	(0.3520)	(0.3663)	(0.0876)
Z_Score	5.3857	2.4771	1.2719***	0.2060***
	(1.8165)	(0.7023)	(0.4898)	(0.1774)
Beta	−4.5431	−4.0712	2.2910***	2.6489***
	(1.2259)	(2.4931)	(2.4877)	(0.6201)
ROA	−0.3730	−0.6571	0.0508***	0.0345***
	(0.2164)	(0.0773)	(0.0584)	(0.0192)
M/B	−2.0954	−0.2374	−0.4388***	−0.0018***
	(1.1811)	(0.2386)	(0.3185)	(0.0593)
LNTA	−5.2643***	−4.9464***	0.3147***	−0.2206*
	(1.6169)	(0.6251)	(0.4360)	(0.1555)
LEVERAGE	2.6631***	0.8890	−3.1427***	−2.6588***
	(1.3816)	(4.1627)	(3.8778)	(1.0354)
PPE	1.4474**	0.7175	−0.5915*	0.1692*
	(2.8839)	(0.6170)	(0.7776)	(0.1535)
CAPEX	2.1766**	0.2984*	−0.9788	−0.1845
	(2.7639)	(0.6409)	(0.7452)	(0.1594)
GROWTH	1.2197	1.1112	0.2529*	0.2514***
	(0.9429)	(0.4025)	(0.2543)	(0.1001)
CASH	0.5626	0.2432	0.0870	0.0525
	(0.2197)	(0.0800)	(0.0592)	(0.0199)
Constants	6.9314***	4.5191***	2.8730***	2.5717***
	(1.2951)	(5.9262)	(1.3938)	(1.4741)
Year Fixed Effect	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes
Observations	163	853	163	853
R-squared	0.5732	0.4669	0.3448	0.2918

This table displays regression results for sensitivity analysis involving a company's idiosyncratic risk and cost of capital (COC) regressed on corporate GHG emissions and control variables. Coefficient estimates with robust standard errors (in parentheses) are provided. Significance levels are denoted by superscripts ***, **, and *, representing significance at the 1%, 5%, and 10% levels, respectively.

of idiosyncratic risk and COC that may lead to potential spurious correlation. The results of this study are robust to a spectrum of industry- and year-level sensitivity tests and tests of endogeneity.

The findings of this study show a positive correlation between higher corporate carbon emissions performance and idiosyncratic risk. In other words, poor corporate carbon emissions performance unfavourably increases company-specific risk. Corporate carbon emissions performance and related information are important for risk management. It impacts the evaluation of carbon-related liabilities and assets and, therefore, the cost of capital (COC). This study's findings complement Jo and Na (2012) and Cooper et al. (2018), who document the higher operational risk exposures of companies with higher carbon emissions performance.

This study shows that higher corporate carbon emissions performance results in a higher cost of capital (COC). In other words, every additional metric ton of carbon emissions results in an average of 18.5% higher capital costs. This indicates that the capital market considers corporate carbon emissions in its risk assessments, leading to a higher cost for polluting companies. The measurements can help companies reduce their carbon emissions performance and COC and manage their optimal financing choices. This is consistent with findings in prior literature by Sharfman and Fernando (2008) and Bui et al. (2020). They provide evidence supporting the capital market's robust environmental risk assessment for lending or investment purposes.

The study's findings have several important implications for companies and their managers, regulators, and the accounting literature. It echoes the argument by Jo and Na (2012) that companies can control for idiosyncratic risk by managing their environmental performance. Corporate exposure to carbon emissions performance differs depending on companies' commitment to managing carbon emissions risks, eventually impacting the capital cost. The findings also help construct a better conceptual understanding of corporate strategic choice in managing corporate carbon emissions (He et al., 2021). This complements the argument by Sharfman and Fernando (2008) that improving corporate carbon emissions pays off with better corporate risk management and eventually reduces the company's cost of capital (COC).

The results suggest that Australian-listed companies with high carbon emissions must regularly reassess their borrowing abilities. The capital markets apply higher interest rates to high-carbon-emitting companies due to future uncertainty related to carbon emissions and their implications for companies (Li et al., 2014; Maaloul, 2018). This uncertainty also contributes to corporate carbon emissions reduction strategies and initiatives to mitigate carbon emissions risks. This study recommends that regulators consider the financial risks associated with corporate carbon emissions during the development, evaluation, and update of current legislation for carbon-related performance.

Prior literature recommends that a more advanced accounting system is required to meet the need for a low-carbon-emissions economy (He et al., 2021; Ratnatunga et al., 2011). The current study's finding not only corroborates this argument but also echoes the recommendation by Luo and Tang (2014) to expand the accounting, auditing and management teaching and training program to cover practice in a green business environment. The findings of this study contribute to the schemes that recognize carbon emissions allowance and its implications in financial accounting frameworks, as highlighted in prior literature (Lovell, 2014; Lovell et al., 2013; Warwick & Ng, 2012).

This study is not without limitations. The study sample includes only Australian-listed companies. The findings apply only to listed companies, limiting their generalisability to all companies, including non-listed ones. The study does not evaluate the costs of managing corporate carbon emissions, which may be interesting to investigate from lenders' and market participants' perspectives. Future studies could investigate the moderating impact of these costs on the association between corporate carbon emissions and the cost of capital (COC).

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that all have approved the order of authors listed in the manuscript of us.

We also warrant that the article is the named authors' original work, which has neither been published prior nor is it under consideration for publication elsewhere.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication concerning intellectual property, including the timing of publication. In so doing, we confirm that we have followed the regulations of our institutions concerning intellectual property.

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Data availability

The authors do not have permission to share data.

Appendix A

Variable definitions.

Category/Measure	Definition/Measurement
Carbon emissions/$GHG_{i,t}$	Total GHG emissions (in metric tons) in year t represent the sum of direct emissions from GHG sources owned or controlled by the company (Scope 1) and indirect emissions resulting from the company's consumption of electricity, heat, or steam (Scope 2)
Emissions intensity / GHG_INT$_{i,t}$	GHG emissions intensity in year t is calculated as the proportion of total GHG emissions to total sales
Weighted average cost of capital (WACC) / COC$_{i,t}$	The cost of capital for firm i in year t is determined as follows: $WACC = \left(\frac{E}{D+E}\right)r_E + \left(\frac{D}{D+E}\right)r_D(1-T)$ where: $E = firm's\ equity\ market\ value$ $D = market\ value\ of\ the\ firm's\ debt$ $r_E = cost\ of\ equity\ capital$ $r_E = r_F + \beta_E(r_M - r_F)$ $r_M = market\ rate\ of\ return$ $r_F = risk\text{-}free\ rate\ of\ return$ $\beta_E = \frac{Cov(r_E,\ r_M)}{Var(r_M)}$ *measures for systematic risk* $r_D = cost\ of\ debt\ capital$ $r_D = [[(SD/TD) \times (CS \times DF)] + [(LD/TD) \times (CL \times DF)]] \times [1\text{-}T]$ $SD = short\text{-}term\ debt\ (in\ millions\ of\ C\$)$ $TD = total\ debt\ (in\ millions\ of\ C\$)$ $CS = cost\ of\ short\text{-}term\ debt\ (\%)$ $DF = debt\ adjustment\ factor\ (\%)$ $LD = long\text{-}term\ debt\ (in\ millions\ of\ C\$)$ $CL = cost\ of\ long\text{-}term\ debt\ (\%)$ $T = tax\ rate$
Z_Score	Default risk is assessed using the Altman's Z-Score, originally formulated by Edward Altman in 1968, and subsequently multiplied by −1 to ensure that elevated values indicate a greater default risk, $Altman's\ Z-Score = 1.2 * (Working\ Capital / Tangible\ Assets) + 1.4 * (Retained\ Earnings / Tangible\ Assets) + 3.3 * (EBIT / Tangible\ Assets) + 0.6 * (Market\ Value\ of\ Equity / Total\ Liabilities) + (Sales / Tangible\ Assets)$
Beta	The company's systemic risk measures the correlation between the security's volatility and the market's volatility, indicating its sensitivity to broader market movements,
ROA	Return on assets (ROA) is calculated as the percentage ratio of earnings before interest and taxes (EBIT) to total assets (TA), serving as an indicator of a company's profitability, $ROA = \frac{EBIT}{TA}$
M/B	Market to book value is determined by the ratio between the market value and the book value of equity of company i at the end of year t,
Company Size/LNTA$_{i,t}$	The natural logarithm of total assets of company i at the end of year t,
Debt or leverage/Leverage$_{i,t}$	Leverage, calculated as the ratio of total debts to total assets for company i at the end of year t,
Property, plant, and equipment/Leverage$_{i,t}$	The proportion of property, plant, and equipment relative to total sales for company i at the end of year t,
Capital expenditure/Capex$_{i,t}$	Capital expenditure as a fraction of total sales for company i at the end of year t,
Revenue growth/Growth$_{i,t}$	The year-on-year percentage change in sales for company i at the end of year t,
Liquidity/Cash$_{i,t}$	The ratio of cash to total assets for company i at the end of year t,

Source: Bloomberg dataset

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