CARBON PERFORMANCE AND DEBT MATURITY: THE ROLE OF DISCLOSURE AND INFORMATION ASYMMETRY

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Abstract

Carbon performance and the disclosure of other non-financial information can reduce information asymmetries between managers and stakeholders. However, their interaction as determinant factors of debt maturity is yet to be explored. Using a sample of European listed firms, we explore the moderating effects of different types of non-financial disclosure and information asymmetry detected by the market on the relationship between carbon performance and debt maturity. The results show a strong positive effect of structured information in contrast to the lack of significance of non-structured reports. Adding the level of information asymmetry captured by the market, structured information and non-structured corporate social responsibility reports strengthen the positive effect of carbon performance on debt maturity in low information asymmetry contexts but only mitigate it in high information asymmetry contexts. Meanwhile, environmental information had a negative effect in both contexts, suggesting that this costly report would be redundant with respect to mandatory data on carbon emissions.

1. INTRODUCTION

The European Union (EU) is committed to protecting its natural capital, safeguarding its citizens' health and well-being, and becoming a resource-efficient, green, and competitive low-carbon economy. The European Commission's (EC) Green Deal strives to ensure zero net greenhouse gas (GHG) emissions by 2050, with ambitious intermediate targets for 2030 already in place and 2040 currently under negotiation. Information is crucial for this long-term process. Directive 2003/4/EC on public access to environmental information was the first of several regulations to be enacted to guarantee the availability of regulations, policies, and data gathered by public authorities to allow social participation and access to justice in environmental matters. Considering the main role of businesses in achieving a low-carbon economy, firms' information on their environmental performance, including the risks and opportunities derived from environmental issues, is of interest to stakeholders, civil society organizations, and citizens. In search of homogeneous disclosures that facilitate comparability and decision-making, the EU Corporate Sustainability Reporting Directive (CSRD) entered into force in January 2023, affecting the information to be issued in 2025 (about the firm's 2024 activity) by large companies, listed SMEs, and some non-EU companies, although the adoption of sector-specific European Sustainability Reporting Standards was postponed until mid-2026.

The increasing pressure from institutional standards (Abraham & Shrives, 2014) to decarbonize the economy prompts firms to reduce their carbon emissions and maintain legitimacy with respect to their environmental behavior (Borghei, 2021), turning performance and disclosure into relevant factors for firms and their stakeholders' decision-making (Cormier et al., 2005). Studies have increasingly focused on how environmental performance and reporting affect companies' financial performance (Borghei et al., 2018a; Brogi et al., 2022; Trumpp & Guenther, 2017). Financial institutions are progressively integrating environmental considerations into their credit evaluations, which influences the cost of capital and firms' access to financing (Jung et al., 2018; Kim et al., 2015).

This study contributes to a recent line of research examining how environmental performance affects financial debt (Fernández-Cuesta et al., 2019; Ferreras et al., 2024; Tascón et al., 2021) and is framed in a research stream on the consequences or impacts of environmental disclosure (Borghei et al., 2018b; Schiemann & Sakhel, 2019). Specifically, we analyze how carbon disclosure and information asymmetry affect the capital structure of carbon performers in the European context. Since the disclosure of non-financial information can be used as an asymmetry information reduction tool, we hypothesize that corporate social responsibility (CSR) and specific environmental reporting moderate this relationship, helping or hindering carbon performers from obtaining longer debt maturity, depending on the information asymmetry context.

This study analyzed carbon emissions and financial data using a sample of listed firms from 25 European countries during the period 2005-2019. The study applied the generalized method of moments (GMM) to analyze the impact of reporting and information asymmetry on carbon performers' debt maturity. We used three different variables related to the voluntary disclosure of non-financial information and the bid-ask spread as proxies for firm's information asymmetry.

Our results indicate that reporting CSR and adopting Global Reporting Initiative (GRI) guidelines increase the positive effect of carbon performance on debt maturity in the contexts of low information asymmetry. Additionally, environmental reporting has a strong negative impact on firms in both high- and low-information-asymmetry contexts. This could be explained by carbon performers in the contexts of high information asymmetry, finding long-term debt less attractive, and by the information released not being useful enough to provide stakeholders with a complete picture of firms' environmental behavior.

The remainder of this study is organized as follows. In Section 2, we discuss the previous literature and provide our key hypotheses. Section 3 outlines the methodology and proposed model. Section 4 presents our findings. Finally, Section 5 presents concluding remarks and provides practical implications.

2. LITERATURE REVIEW AND HYPOTHESES

2.1. Carbon performance and capital structure

The growing stringency of environmental regulations centered on carbon emissions exposes firms to the transition risk associated with emission reduction policies (Alogoskoufis et al., 2021). Thus, carbon performance becomes a relevant factor in firm's and stakeholders' decision-making in the context of insufficient data on the environmental elements that address future firm performance (Hassel et al., 2005; TCFD, 2020).

One strand of the literature focuses on the effects of environmental policies and carbon performance on decisive factors of firm financing, such as the cost of capital (Kim et al., 2015; Jung et al., 2018). Compliance with environmental regulations and lower carbon risk reduce potentially derived debts and losses (Kim et al., 2015; Nishitani & Kokubu, 2012). However, financial institutions are increasingly concerned about sustainability and environmental quality issues, changing their credit policies by assessing carbon risk and increasing investor perceptions of the subject (Brogi et al., 2022; Jung et al., 2018; Herbohn et al., 2019). Accordingly, carbon performers are rewarded with better financing conditions (Du et al., 2017; Kim et al., 2015).

In the European context, Fernández-Cuesta et al. (2019) find that carbon performance is a relevant factor in the capital structure of firms. Better carbon performance eases access to financing by reducing information asymmetry, specifically the long-term debt required for the transition to cleaner production. This is in line with Lemma et al. (2021), who find that firms with a higher environmental commitment are rewarded with better reputation and credit ratings as well as reduced information asymmetry costs that allow them to easily access long-term financing. This suggests that carbon performance is key to firms' financing and, as an information asymmetry tool, it determines the maturity of their debt. In this study, we analyze the effect of information asymmetry in two ways: (1) as a result of different types of information issued by firms, and (2) as a contextual mechanism of information transmission between insiders and outsiders in the market.

2.2. Carbon performance, non-financial reporting and information asymmetry

Information asymmetry distorts stakeholders' decision-making (Lashitew, 2021); hence, the effects of information asymmetry on firms depend on the stakeholders directly interested in that information and the decisions they make with respect to the firm as a consequence of that information. A firm's environmental performance and its disclosure are accountable to three levels of stakeholders (Cormier et al., 2005): shareholders and debtholders, investors, and other stakeholders such as governments, customers, suppliers, employees, and the rest of society. Stakeholders obtain information to assess a firm's environmental risks (potential costs and liabilities derived from a lack of compliance, fines, taxes, etc.) (Kim et al., 2015; Nishitani & Kokubu, 2012), and potential operating revenues derived from environmental strategies (Porter & van der Linde, 1995), thus reducing information asymmetry between stakeholders and managers (Cui et al., 2018). Concerning debt holders, shareholders, and investors, better environmental performance of the firm would be rewarded with better financing conditions, such as lower costs of capital (Richardson & Welker, 2001; Velte et al., 2020; Zhang & Liu, 2020) and higher credit amounts (Fernández-Cuesta et al., 2019). The current study focuses on the effect of some features of disclosure of firms' environmental information on the capital structure, such as the level of discretion from the firm and the information asymmetry detected by the market for that firm.

The theoretical framework builds on agency theory, which explains that disclosure reduces the information asymmetry between managers and creditors to obtain better credit terms. However, the socialized view of agents and principals requires a wider perspective (Cormier et al., 2005; Lubatkin et al., 2007), which can be provided by institutional and proprietary cost theories, as well as legitimacy and stakeholder theories. Institutional theory promotes standardized disclosure, originating at a valuable minimum level of disclosure, but not inducing the addition of firm-specific details, in line with proprietary costs theory (Abraham & Shrives, 2014; Cormier et al., 2005; Verrecchia, 1983). For listed companies, proprietary costs theory must adopt a more comprehensive perspective to coordinate with legitimacy and stakeholder theories (Abraham & Shrives, 2014). Legitimacy theory supports carbon disclosure to avoid scrutiny (Braam et al.,

2016), which is the minimum information required to satisfy social and stakeholder requests on the firm's environmental risks and policies (Borghei, 2021; Stanny, 2013). Stakeholder theory explains voluntary carbon disclosure to provide information on environmental compliance to the varied interests of a firm's stakeholders (Borghei, 2021; Liao et al., 2015). Firms in more polluting industries, or those perceived to have a higher impact on society (such as listed firms), experience higher stakeholder pressure and monitor their environmental performance (Berrone & Gómez-Mejía, 2009).

For our baseline hypothesis, we consider a straightforward relationship between carbon performance and debt maturity. From the perspective of the discretion/obligation of disclosure, firms subject to the European Union Emissions Trading System (EU-ETS) do not decide whether to publish their carbon performance, since the EC makes it available to the public, disabling the possibility of companies using this information to their advantage (Luo & Tang, 2014). Objective figures of emissions reduce information asymmetry for stakeholders (Velte et al., 2020) by providing data on the quantity and timing of GHG emissions, pace of GHG reduction, and compliance with regulations.

According to pecking order theory (POT), the existence of information asymmetry between managers and stakeholders creates a financing hierarchy due to adverse selection costs (Myers & Majluf, 1984) and affects the structure of debt maturity (Wu et al., 2022). The reduction in information asymmetries can reduce the cost of capital and the risk of default (Derrien et al., 2016), thus facilitating firms' access to new debt financing with longer maturity. High levels of information asymmetry cause firms to use less long-term debt, because their costs are more sensitive to the information environment (Gao & Zhu, 2015). Considering the previously stated positive impact of carbon performance on firms' capital structure and its ability to reduce information asymmetry between firms and lenders, we expect better carbon performance to provide companies with higher debt maturity. Therefore, we propose the following baseline hypothesis.

H0: Carbon performance positively affects firms' debt maturity.

However, it is difficult to compare the carbon performance of different firms and industries by considering only direct emissions without considering all emissions

accumulated in their value chain (Hoffmann & Busch, 2008). Stakeholders in general, and creditors in particular, may not obtain a complete picture of a firm's carbon performance and, therefore, may need additional information about the firm's environmental policies. Non-financial information can be disclosed to reduce information asymmetry (Watson, 2015). This study analyzed voluntary environmental reporting in three formats: CSR, GRI standards, and specific environmental information.

CSR contains environmental information that is internally decided with respect to content and detail, with firms searching for a higher reputation and legitimacy, engaging in CSR activities and reporting (Kilian & Hennigs, 2014). For new disclosers, mere awareness and quantification allow the firm to detect inefficiencies, improve processes, and incorporate innovation (Borghei et al., 2018a; Lash & Wellington, 2007). When reporting new and useful information to stakeholders, information asymmetry is reduced, with a subsequent positive effect on debt maturity through reduced default risk (Derrien et al., 2016). CSR reporting can further affect debt maturity because firms that voluntarily adopt CSR policies demonstrate less opportunistic behavior (Bénabou & Tirole, 2010; Eccles et al., 2012) and reduce reputational risk (Cui et al., 2018; Zhu et al., 2014). This increased reputation contributes to reducing the cost of capital (Botosan, 2006; Cuadrado-Ballesteros et al., 2016) and capital constraints (Cheng et al., 2014) and improves long-term predictions from creditors, giving access to higher long-term financing (Yang et al., 2018). Among different CSR sub-dimensions, environmental disclosure has been found to be the most influential on creditors' decisions to offer favorable interest rates (Hamrouni et al., 2019). This leads to high-CSR firms having longer debt maturity than other firms, as it is perceived as a mechanism that may substitute short-term debt for monitoring purposes (Nguyen et al., 2020).

A controversy concerning the effect of environmental disclosure on information asymmetry comes from the issuing of voluntary information[1], as firms can select

[1] Linsley & Shrives (2006) evidenced that firms with lower levels of environmental risk were disclosing more risk information. Depoers et al. (2016) find that voluntary non-structured GHG information is widely variable in respect to quality and frequency while Dragomir (2012) identify unexplained figures and methodological inconsistencies in non-structured sustainability reports. Similarly, in unregulated settings Braam et al. (2016) detect that sustainability reports lack information to adequately delimitate the effects of the firm's activities on the environment.

information favorable to their interests, thus giving preference to good news on the environmental performance and avoiding to mention the less favorable news (Datt et al.,2019; Guo et al.,2020). Considering economic principles and competitive analysis, the discretionary approach provides voluntary information when a firm's benefits surpass the disclosure costs (Borghei et al., 2018a). Issuing firm-specific environmental information and policies may be costly if competitors, other stakeholders, and/or pressure groups use this information to harm or compromise a firm's interests and future performance (Dye, 1985; Verrecchia, 1983) although this type of costly information enhances disclosure credibility (Skinner, 1994). Furthermore, some firms engage in 'greenwashing' (Fan, 2021; Lashitew, 2021), which is a symbolic action that appears as if firms conform to the norm and present themselves as environmentally responsible to the public when they are not (Ramus & Montiel, 2005; Suchman, 1995). These biases in disclosed environmental information add information asymmetry and threat legitimacy (Datt et al., 2019; Peters & Romi, 2013). Due to stakeholder scrutiny, these courses of action are likely to be perceived and penalized (Rhee & Haunschild, 2006), resulting in lower financial performance (Walker & Wan, 2012). According to the POT, information-opaque firms tend to cause moral hazard problems for lenders. In this context, short-term debt can be used as an agency problem mitigation tool because it forces lenders to monitor managers more frequently (Stulz, 2003). Regarding information asymmetry, firms' choice of debt maturity depends on their private information on the expected cash flows and default probabilities. Firms with more favorable information on carbon performance prefer short-term debt (Goyal & Wang, 2013). Unfavorable information makes long-term debt preferable because a firm's securities are overvalued, and creditors would offer better credit terms (Schmid-Klein et al., 2002).

One way to avoid penalization by stakeholders in general, and particularly by creditors, is to adhere to a structured format of environmental reports proposed by an external organism that is generally accepted in environmental proficiency (Skinner, 1994). Thus, a firm publishing voluntary environmental reports within the GRI principles would send a message to its stakeholders about the lack of discretion and transparency in both favorable and unfavorable pieces of information, which increases both the extent of disclosure and credibility (Rankin et al., 2011) and reduces the likelihood of firms

engaging in greenwashing practices (Ruiz-Blanco et al., 2022). This would mean an additional reduction in information asymmetry, and structured/formalized information would allow stakeholders to monitor managers' environmental policies and performance (Luo & Tang, 2023). In this line, Luo & Tang (2023) find that firms that follow GRI standards are better carbon performers with proactive carbon strategies and actively engage with their stakeholders.

Therefore, we expect that disclosing voluntary nonfinancial information will affect the positive relationship between carbon performance and debt maturity, this effect being opposite for structured and nonstructured information, as formulated in our first hypothesis.

H1: The disclosure of structured (unstructured) voluntary non-financial information positively (negatively) moderates the relationship between carbon performance and debt maturity.

Finally, considering that the relationship between disclosure and information asymmetry can be contingent on firm contextual factors (Schiemann & Sakhel, 2019), this study analyzes information asymmetry as a part of the market mechanism. Investors' price protection compensates for the disadvantages of opaque information by reducing the market value of the firm, causing adverse selection costs for external financing (Fan et al., 2021; Fosu et al., 2016; Watts & Zimmerman, 1986). Additionally, asymmetric information allows managerial discretion and risk-shifting behavior, thereby increasing agency costs (Leary and Roberts, 2010).

Firms with higher information asymmetry between their managers and stakeholders have greater incentives to camouflage inferior carbon policies and less pressure to avoid them (Fan, 2021; Schiemann & Sakhel, 2019). Given that information on real firms' performance is not directly observable by stakeholders, poor performing firms may imitate good performers' disclosures to simulate better performance, although objective disclosures such as data on carbon emissions and structured reports are hardly biased (Datt et al., 2019).

With lower information asymmetry in the market, the negative effects of information gaps incentivize managers to publicly disclose private information to stimulate the optimal allocation of capital (Verrecchia, 2001) and lower transaction costs (Diamond & Verrecchia, 1991)

With greater information asymmetry in the market, informed managers can hide poor performance. Stakeholders cannot distinguish the intended good performance from the real one because the market does not penalize this behavior and higher equity costs are indiscriminately applied to both good and bad performers.

In summary, we expect the moderating role of disclosure to vary depending on the context of a firm's information asymmetry. When non-financial information reports are used to provide distorted information about a firm's strategies and therefore do not help reduce information asymmetry, we expect that disclosure has a negative impact on the effect of carbon performance on debt maturity. On the contrary, when firms use non-financial information reports to provide more complete insights into the firm, helping to reduce information asymmetry, the effect of disclosure is positive. Therefore, we propose the following hypothesis:

H2: In contexts of low (high) information asymmetry, disclosure has a positive (negative) effect on the relationship between carbon performance and debt maturity.

3. DATA AND METHODOLOGY

3.1. Sample

The data were obtained from several sources. Financial and corporate governance data were collected from Thomson Reuters Eikon, whereas carbon emission data were provided by the European Commission through the European Union Transaction Log (EUTL). Our sample period, from 2005 to 2019, includes 3,077 firm-year observations from 260 listed firms across 25[2] European countries participating in the EU-ETS.

[2] All 31 countries excepting Estonia, Greece, Hungary, Liechtenstein, Luxembourg, and Malta.

3.2. Methodology and model

We employ the generalized method of moments (GMM) proposed by Arellano (2003) to address potential endogeneity, using the lagged values of all right-hand side variables as instruments in the models. Arellano & Bond (1991) and Blundell & Bond (1998) indicate that flexibility allows it to handle unobservable heterogeneity and minimize the potential collinearity between the study's variables and the error term. Additionally, we apply the Hansen test and the AR2 statistic to validate the instrument choices and the overall model specification, thereby enhancing its reliability.

We conduct a multivariate analysis to regress environmental performance on debt maturity by adding control variables that influence this relationship. Therefore, our first empirical model for testing H0 is as follows:

$$MAT_{it} = \alpha_0 + \alpha_1 MAT_{it-1} + \alpha_2 CEP_{it} + \alpha_3 TANG_{it} + \alpha_4 MTB_{it} + \alpha_5 LIQ_{it} + \alpha_6 SIZE_{it} + \alpha_7 PROF_{it} + \alpha_8 SDG13_{it} + \alpha_9 INDEP_{it} + \alpha_{10} GDP_{it} + \sum_{k=1}^{12} S_k + \sum_{k=1}^{25} C_k + \sum_{t=2005}^{2019} Y_t + \varepsilon_{it} \quad (1)$$

To test H1, we modify the previous model by introducing several non-financial information disclosure variables as moderators of carbon performance:

$$MAT_{it} = \alpha_0 + \alpha_1 MAT_{it-1} + \alpha_2 CEP_{it} + \alpha_3 DISC_{it} + \alpha_4 CEP_{it} * DISC_{it} + \alpha_5 TANG_{it} + \alpha_6 MTB_{it} + \alpha_7 LIQ_{it} + \alpha_8 SIZE_{it} + \alpha_9 PROF_{it} + \alpha_{10} SDG13_{it} + \alpha_{11} INDEP_{it} + \alpha_{12} GDP_{it} + \sum_{k=1}^{12} S_k + \sum_{k=1}^{25} C_k + \sum_{t=2005}^{2019} Y_t + \varepsilon_{it} \quad (2)$$

Finally, to test H2, we add a proxy for a firm's information asymmetry to (2) as follows:

$$MAT_{it} = \alpha_0 + \alpha_1 MAT_{it-1} + \alpha_2 CEP_{it} + \alpha_3 CEP_{it} * DISC_{it} + \alpha_4 CEP_{it} * DISC_{it} * HIGH\_IA_{it} + \alpha_5 TANG_{it} + \alpha_6 MTB_{it} + \alpha_7 LIQ_{it} + \alpha_8 SIZE_{it} + \alpha_9 PROF_{it} + \alpha_{10} SDG13_{it} + \alpha_{11} INDEP_{it} + \alpha_{12} GDP_{it} + \sum_{k=1}^{12} S_k + \sum_{k=1}^{25} C_k + \sum_{t=2005}^{2019} Y_t + \varepsilon_{it} \quad (3)$$

MAT is a firm's debt maturity and a dependent variable. CEP is one of the main independent variables in this study and represents a firm's carbon performance. DISC corresponds to three different disclosure proxies: CSR, which takes a value of 1 when the firm engages in CSR disclosure and 0 otherwise; GRI, which takes a value of 1 when the firm provides CSR information according to the GRI guidelines and 0 otherwise; and ENV, specific for environmental reporting, obtained by running a Principal Components

Analysis (PCA) on three different variables[3]: ENVEXP, ENVINV, and ENVEUR (vid. Table 1). The first component is selected and used to code ENV, which takes a value of 1 for higher component scores when the firm engages in environmental disclosure, and 0 otherwise. The interaction term CEP*DISC enables us to assess the moderating effect of each disclosure variable on carbon performers' debt maturity. HIGH_IA is our proxy for information asymmetry, which takes a value of 1 for firms with a bid-ask spread above the median of each industry and year and a value of 0 for firms with a spread below that median. The interaction term CEP*DISC*HIGH_IA allows us to assess the differential effects of environmental disclosures on carbon performers in different information asymmetry contexts. We introduce the market-to-book ratio (MTB) as a common information asymmetry control variable (Schiemann & Sakhel, 2019). As it is related to the investment opportunities of the firm, it is also frequently used to control for debt maturity (Nguyen et al., 2020). Following previous studies such as Anwar & Sun (2015), Fernández-Cuesta et al. (2019), Frank & Goyal (2009), Kieschnick & Moussawi (2018) or Rajan & Zingales (1995) among others, tangibility of assets (TANG), liquidity (LIQ), firm size (SIZE), and profitability (PROF) are the most frequently employed control variables in capital structure research.

Table 1. Definition of variables

Variable	Definition	Source
MAT	Long-term financial debt to total financial debt	Eikon
CEP	The negative total verified direct carbon emissions produced by the firm to total sales. Calculated as CEP = - log(emissions)/log(sales)	EUTL
Disclosure variables		
CSR	The company publishes a separate CSR report or publishes a section in its annual report on CSR	Eikon
GRI	CSR report or data published within the framework of GRI (Global Reporting Initiative) principles	Eikon
ENV	Principal component combining three environmental reporting variables: ENVEXP, ENVINV and ENVEXPINV. High scores in this variable are associated with higher environmental reporting by firms	Eikon
ENVEXP	The company reports on making environmental expenditures	Eikon
ENVINV	The company reports on making proactive environmental decisions to reduce future risks or increase future opportunities	Eikon
ENVEUR	The company reports on the total amount of its environmental expenditures and investments	Eikon
Information asymmetry variables		
SPREAD	Bid-ask spread, calculated as high minus low trading price of the day, divided by the midpoint between the two	Eikon

[3] The first extracted component captures 85.50% of the total variance of the three variables.

HIGH_IA	Dummy variable that takes a value of 1 when a firm has a bid-ask spread higher than the industry-year median, and 0 otherwise	Eikon
Control variables		
MTB	Logarithm of market-to-book ratio	Eikon
TANG	Net property, plant, and equipment to total assets	
LIQ	Current assets to current liabilities	Eikon
SIZE	Logarithm of total assets	Eikon
PROF	Operating income before depreciation to total assets. Operating income is measured as earnings before interests, taxes, depreciation, and amortization (EBITDA)	Eikon
SDG13	Self-declaration of adherence to Goal 13 of SDG	Eikon
INDEP	Proportional measurement of the independent directors on the board	Eikon
GDP	Annual growth of the Gross Domestic Product of each country	Eikon

As an environmental control variable, we introduce a firm's adherence to the 13th Sustainable Development Goal (SDG) and use board independence (INDEP) as a governance control variable. In addition, we include growth of the Gross Domestic Product (GDP) as a macro control variable. Finally, we use dummies to control for effects related to sector, country, and year. The definitions of the variables are presented in Table 1.

4. EMPIRICAL RESULTS

4.1. Descriptive statistics

Table 2 reports the summary statistics for the variables used in all models. The mean value of debt maturity (our dependent variable) was 68.42%, while the mean value of CEP was -0.3740, similar to those found by Castro et al. (2021) and Fernández-Cuesta et al. (2019), with some firms achieving zero direct GHG emissions, as shown by its maximum value. Regarding the disclosure variables, the mean values indicate that just over half of the firms in the sample engage in voluntary disclosure of general CSR information, while only 36.20% report specific environmental information. Firms reporting according to the GRI principles account for 40.10% of the observations.

Table 2. Sample statistics

	Mean	SD	Min	Max
MAT	0.6842	0.2596	0.0000	1.0000
CEP	-0.3740	0.2671	-0.8095	0.0000
CSR	0.5252	0.4994	0.0000	1.0000
GRI	0.4010	0.4902	0.0000	1.0000

ENV	0.3620	0.4807	0.0000	1.0000
HIGH_IA	0.5301	0.4992	0.0000	1.0000
TANG	0.4025	0.2122	0.0000	0.9308
MTB	2.1775	2.4693	-0.2369	17.3555
LIQ	1.4158	0.7452	0.2951	5.7314
SIZE	21.9199	2.1781	15.1160	25.6338
PROF	0.1113	0.0717	-0.5625	0.4975
SDG13	0.0305	0.1721	0.0000	1.0000
INDEP	0.3156	0.4648	0.0000	1.0000
GDP	0.0173	0.0278	-0.1484	0.2516

Note: The variable definitions are presented in Table 1.

Table 3 shows the mean differences in debt maturity between the two groups obtained by dividing the sample by the median of the main independent variables. The division between high- and low-emitting firms shows that the latter benefit from higher debt maturity, which is consistent with the literature. Dividing by information asymmetry, on the other hand, does not manifest a significant difference in debt maturity. The reporting of non-financial information has a positive effect on both high- and low-IA firms, especially in the case of CSR reports, which seem to provide a greater advantage than GRI or environmental reporting.

Table 3. Mean differences of debt maturity (t-test)

Variable	0	1	Difference
High (1) vs low (0) carbon emissions			
Emissions	0.7068	0.6567	-0.0500***
High (1) vs low (0) information asymmetry			
HIGH_IA	0.6790	0.6871	0.0081
Disclosure vs no disclosure			
CEP	0.6047	0.7561	0.1514***
GRI	0.6399	0.7504	0.1105***
ENV	0.6440	0.7551	0.1111***
Disclosure vs no disclosure for high IA (HIGH_IA = 1)			
CSRep	0.6085	0.7606	0.1521***
GRI	0.6418	0.7605	0.1187***
ENV	0.6633	0.7615	0.1182***
Disclosure vs no disclosure for low IA (HIGH_IA = 0)			
CSRep	0.5987	0.7513	0.1526***
GRI	0.6333	0.7420	0.1087***
ENV	0.6433	0.7473	0.1040***

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

Table 4 presents the correlation coefficients for the variables used in this study. Debt maturity is strongly and positively related to the three reporting variables, as expected

from the reduction in credit risk achieved by higher social and credit ratings (Wu et al., 2022). Debt maturity is also positively correlated with CEP, market-to-book ratio, liquidity of the firm, size, and board independence and negatively related to GDP growth and high IA, although the latter is non-significant. CEP is positively associated with two disclosure variables but, interestingly, not with environmental reporting. This could be an early sign that this type of reporting might be used to cover up for an underwhelming performance in this area. IA has negative correlations with size, profitability, and the market-to-book ratio and positive with liquidity. Finally, it is worth highlighting that there are particularly high positive correlations between firm size and all three reporting variables. This is consistent with previous findings that larger firms are under more stakeholder pressure and scrutiny; therefore, they are expected to commit to higher levels of CSR and become environmentally proactive (Seroka-Stolka & Fijorek, 2020; Wickert et al., 2016). The same applies to board independence, as independent board members are more willing to pursue the interests of the company's stakeholders and disclose more and better non-financial information (García-Sánchez et al., 2011; Vitolla et al., 2020).

Table 4. Correlation matrix

	MAT	CEP	CSR	GRI	ENV	HIGH_IA	TANG	MTB	LIQ	SIZE	PROF	SDG13	INDEP	GDP
MAT	1													
CEP	0.0738*	1												
CSR	0.2912*	0.1181*	1											
GRI	0.2087*	0.0772*	0.7754*	1										
ENV	0.2057*	0.0399	0.6553*	0.6185*	1									
HIGH_IA	0.0155	0.0035	-0.0095	-0.039	0.0279	1								
TANG	-0.0391	-0.1827*	-0.1782*	-0.0956*	-0.0122	0.0116	1							
MTB	0.1247*	0.0098	0.0916*	0.0445	-0.0041	-0.1054*	-0.1647*	1						
LIQ	0.0947*	-0.0659*	-0.1528*	-0.1070*	-0.0832*	0.0859*	-0.0883*	-0.0068	1					
SIZE	0.3064*	0.1219*	0.6816*	0.6028*	0.5371*	-0.0690*	-0.2533*	0.0914*	-0.2669*	1				
PROF	0.0014	-0.0522*	0.0668*	0.0920*	0.038	-0.0897*	0.0674*	0.2757*	0.1252*	0.0518*	1			
SDG13	0.0031	0.0318	0.1688*	0.1861*	0.1295*	-0.03	-0.024	0.0269	-0.0259	0.1117*	0.0034	1		
INDEP	0.1822*	0.0868*	0.5574*	0.5302*	0.4547*	-0.0494*	-0.1392*	0.0353	-0.0995*	0.5017*	0.0456	0.1436*	1	
GDP	-0.0554*	-0.0023	-0.0953*	-0.0849*	-0.0818*	-0.0099	0.0710*	0.0113	0.042	-0.1140*	0.0612*	-0.0188	-0.0327	1

Note: * denotes significance at the 1% level.

4.2. Moderating role of non-financial disclosure

Table 5 presents the regression results used to test our first hypothesis on the impact of non-financial information disclosure on the relationship between debt maturity and carbon performance. Specifically, Column 1 shows the baseline relationship, with CEP

having a positive and significant effect on debt maturity. This is in line with Fernández-Cuesta et al. (2019), who found that better carbon performance induces higher long-term financial debt. Columns 2 to 4 show the moderating effects of the three disclosure variables. The CEP coefficient remains positive and significant across all three regressions. Column 2 shows that both the disclosure of CSR information and its interaction with CEP have positive yet non-significant coefficients. By contrast, in Column 3, both the GRI disclosure variable and its interaction with CEP show a positive and significant effect. Finally, in Column 4, the direct effect of environmental reporting on debt maturity is positive and significant, whereas its interaction with CEP is positive and non-significant.

Table 5. Effect of non-financial disclosure on the relationship between carbon performance and debt maturity

	(1) Baseline	(2) CSR	(3) GRI	(4) ENV
MAT_{t-1}	0.3890***	0.3971***	0.4209***	0.3966***
	[0.0157]	[0.0124]	[0.0171]	[0.0145]
CEP	0.0996***	0.0433**	0.0415**	0.1084***
	[0.0150]	[0.0183]	[0.0210]	[0.0178]
CSR		0.0211		
		[0.0144]		
CEP*CSR		0.0374		
		[0.0263]		
GRI			0.0909***	
			[0.0128]	
CEP*GRI			0.1503***	
			[0.0248]	
ENV				0.0596***
				[0.0151]
CEP*ENV				0.0300
				[0.0366]
TANG	0.0172	-0.0264	-0.0411	-0.0011
	[0.0213]	[0.0272]	[0.0287]	[0.0258]
MTB	0.0034***	0.0037***	0.0009	0.0009
	[0.0012]	[0.0011]	[0.0012]	[0.0011]
LIQ	0.0368***	0.0336***	0.0339***	0.0440***
	[0.0047]	[0.0049]	[0.0056]	[0.0056]
SIZE	0.0087***	0.0024	-0.0039	0.0066**
	[0.0030]	[0.0032]	[0.0033]	[0.0031]
PROF	0.3460***	0.4156***	0.3605***	0.3650***
	[0.0440]	[0.0447]	[0.0514]	[0.0618]
SDG13	0.0673***	0.0484***	0.0639***	0.0658***
	[0.0169]	[0.0174]	[0.0158]	[0.0163]
INDEP	-0.0101	0.0072	0.0011	-0.0287***
	[0.0083]	[0.0079]	[0.0084]	[0.0087]

GDP	0.1161**	0.1011**	0.0643	0.1268**
	[0.0509]	[0.0453]	[0.0494]	[0.0531]
Constant	0.1866***	0.3102***	0.4369***	0.2247***
	[0.0713]	[0.0744]	[0.0740]	[0.0695]
Observations	3,077	3,077	3,077	3,077
Number of firms	260	260	260	260
Country Dummies	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES
Hansen Test	205.6	203.8	208.8	203.6
Sig. Hansen	0.359	0.817	0.745	0.820
AR2	1.562	1.575	1.577	1.577
Sig. AR2	0.118	0.115	0.115	0.115

Note: Definitions of the variables are presented in Table 1. The standard errors are indicated in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

These results support H1 because the moderation effect is only apparent for GRI. This is in line with those reports being structured and therefore, this information is more useful for stakeholders, improving the positive effect of carbon performance on debt maturity. The lack of significance of the other two interactions could be explained by the different effects of disclosure depending on the information asymmetry context and, therefore, could be clarified through the results relative to H2.

4.3. Moderating role of information asymmetry on the effect of disclosure

Table 6 presents the joint moderating roles of information asymmetry and non-financial reporting on the relationship between carbon performance and debt maturity. The CEP coefficient remains positive and significant across all six regressions, indicating that improved carbon performance positively effects a firm's debt maturity. Columns 1, 3, and 5 show the effects of CSR, GRI, and environmental reporting, respectively, on firms operating in contexts of high information asymmetry. These three coefficients are negative and significant, indicating that voluntary disclosure has a negative influence on the effect of carbon performance on debt maturity in contexts where information asymmetry is high, either because reporting does not help reduce them or because biased information increases them (in line with institutional and proprietary cost theories). On the other hand, columns 2, 4, and 6 show the effect of CSR, GRI, and environmental reporting for firms operating in low information asymmetry contexts.

Table 6. Joint effect of information asymmetry and non-financial disclosure on the relationship between carbon performance and debt maturity

	CSR		GRI		ENV	
	(1)	(2)	(3)	(4)	(5)	(6)
MAT_{t-1}	0.4132***	0.4255***	0.4567***	0.4533***	0.4058***	0.4053***
	[0.0151]	[0.0160]	[0.0151]	[0.0153]	[0.0175]	[0.0151]
CEP	0.0583***	0.0440**	0.0809***	0.0868***	0.1329***	0.0992***
	[0.0182]	[0.0216]	[0.0151]	[0.0146]	[0.0182]	[0.0191]
CEP*CSR	0.0931***	-0.0284				
	[0.0284]	[0.0208]				
CEP*CSR*HIGH_IA	-0.1272***					
	[0.0247]					
CEP*CSR*LOW_IA		0.1141***				
		[0.0240]				
CEP*GRI			0.0522***	-0.0654***		
			[0.0193]	[0.0194]		
CEP*GRI*HIGH_IA			-0.1067***			
			[0.0227]			
CEP*GRI*LOW_IA				0.1296***		
				[0.0233]		
CEP*ENV					-0.0796***	-0.1123***
					[0.0213]	[0.0197]
CEP*ENV*HIGH_IA					-0.0443**	
					[0.0188]	
CEP*ENV*LOW_IA						0.0641***
						[0.0196]
TANG	-0.0111	0.0018	-0.0650**	-0.0411	0.0339	0.0444
	[0.0302]	[0.0269]	[0.0264]	[0.0256]	[0.0288]	[0.0299]
MTB	0.0039***	0.0035***	0.0006	0.0013	0.0022*	0.0019*
	[0.0012]	[0.0014]	[0.0012]	[0.0012]	[0.0011]	[0.0012]
LIQ	0.0326***	0.0349***	0.0420***	0.0415***	0.0465***	0.0459***
	[0.0067]	[0.0068]	[0.0062]	[0.0054]	[0.0051]	[0.0056]
SIZE	0.0053*	0.0064**	0.0037	0.0050	0.0070**	0.0073**
	[0.0028]	[0.0028]	[0.0035]	[0.0033]	[0.0031]	[0.0032]
PROF	0.3929***	0.4393***	0.3608***	0.3298***	0.2929***	0.3678***
	[0.0601]	[0.0622]	[0.0540]	[0.0550]	[0.0683]	[0.0674]
SDG13	0.0558***	0.0475***	0.0701***	0.0875***	0.0717***	0.0674***
	[0.0165]	[0.0162]	[0.0182]	[0.0173]	[0.0189]	[0.0190]
INDEP	0.0092	-0.0015	-0.0079	-0.0038	-0.0174**	-0.0172**
	[0.0086]	[0.0089]	[0.0082]	[0.0088]	[0.0082]	[0.0083]
GDP	0.1973***	0.1607***	0.1760***	0.1459**	0.2214***	0.1914***
	[0.0528]	[0.0602]	[0.0529]	[0.0568]	[0.0558]	[0.0532]
Constant	0.2400***	0.1934***	0.2775***	0.2461***	0.2050***	0.1803**
	[0.0656]	[0.0652]	[0.0785]	[0.0752]	[0.0728]	[0.0757]
Observations	3,077	3,077	3,077	3,077	3,077	3,077
Number of firms	260	260	260	260	260	260
Country Dummies	YES	YES	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES	YES	YES
Hansen Test	194.2	191.8	196.4	206	210.8	203.5
Sig. Hansen	0.996	0.997	0.994	0.978	0.962	0.984
AR2	1.525	1.601	1.688	1.642	1.538	1.536
Sig. AR2	0.127	0.109	0.0913	0.101	0.124	0.124

Note: Definitions of the variables are presented in Table 1. The standard errors are indicated in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

These three coefficients become positive and significant, indicating their positive influence on the effect of carbon performance on debt maturity for firms operating in low asymmetry contexts, because the reporting provides insightful information that reduces information asymmetry or, at least, does not increase it (consistent with legitimacy and stakeholder theories). These results would be supportive of our second hypothesis. Other additional results are also worth mentioning. While the interactions of the three proxies exhibit the same pattern in the sign of their coefficients, environmental reporting stands out from the other two proxies. CSR and GRI reporting have a net negative (positive) effect at average values in high (low) IA contexts when considering both two-way (CEP*DISC) and three-way (CEP*DISC*HIGH_IA) interactions. However, environmental reporting shows a net negative effect at average values in both contexts and is more intense in the low-IA context. In Column 5, the coefficient of CEP is remarkably stronger in the presence of the two types of environmental information, whereas additional environmental information for better performers exerts a counteracting effect, suggesting that a costly report does not add useful information. For firms with high information asymmetry, favorable information on carbon performance makes long-term debt less preferable considering the undervaluation of firms' securities and worse credit terms (Goyal & Wang, 2013; Schmid-Klein et al., 2002). This could also be because this information is too biased, or perhaps because it lacks sufficient depth and detail about decarbonization strategies that might hamper the future carbon performance of firms and, therefore, reduce the access of such firms to long-term financing. Additionally, GRI reporting has a less negative net impact at average values in high-IA contexts, which is in line with our previous results for H1, indicating that structured information is more effective in reducing asymmetries.

4.4. Robustness checks

As a robustness test, we use two proxies of information asymmetry to check the results in Table 6: stock price volatility and scaled accruals. Following Fuhrmann et al. (2017) and Schiemann & Sakhel (2019), we apply price volatility as an alternative measure of firm's information asymmetry.

Table 7. Replication of previous results with price volatility as an IA proxy

	CSR		GRI		ENV	
	(1)	(2)	(3)	(4)	(5)	(6)
MAT_{t-1}	0.4296***	0.4023***	0.4107***	0.4235***	0.4066***	0.4100***
	[0.0178]	[0.0154]	[0.0156]	[0.0148]	[0.0155]	[0.0147]
CEP	0.0557***	0.0810***	0.0832***	0.0829***	0.1193***	0.1247***
	[0.0195]	[0.0176]	[0.0169]	[0.0153]	[0.0189]	[0.0177]
CEP*CSR	0.0971***	0.0002				
	[0.0221]	[0.0228]				
CEP*CSR*HIGH_IA	-0.1330***					
	[0.0208]					
CEP*CSR*LOW_IA		0.0528**				
		[0.0215]				
CEP*GRI			0.0695***	-0.0193		
			[0.0176]	[0.0189]		
CEP*GRI*HIGH_IA			-0.1385***			
			[0.0216]			
CEP*GRI*LOW_IA				0.0593***		
				[0.0184]		
CEP*ENV					-0.0658***	-0.1054***
					[0.0207]	[0.0240]
CEP*ENV*HIGH_IA					-0.0594***	
					[0.0167]	
CEP*ENV*LOW_IA						0.0451**
						[0.0200]
TANG	-0.0313	-0.0580*	-0.0811**	-0.0678**	0.0120	0.0255
	[0.0298]	[0.0304]	[0.0322]	[0.0286]	[0.0330]	[0.0303]
MTB	0.0041***	0.0048***	0.0009	0.0013	0.0021*	0.0029**
	[0.0012]	[0.0011]	[0.0013]	[0.0012]	[0.0012]	[0.0013]
LIQ	0.0345***	0.0300***	0.0403***	0.0382***	0.0505***	0.0458***
	[0.0054]	[0.0059]	[0.0057]	[0.0055]	[0.0050]	[0.0054]
SIZE	0.0056**	0.0066**	0.0112***	0.0093***	0.0103***	0.0094***
	[0.0027]	[0.0026]	[0.0031]	[0.0029]	[0.0028]	[0.0028]
PROF	0.3644***	0.3608***	0.3537***	0.3741***	0.2473***	0.3013***
	[0.0540]	[0.0657]	[0.0578]	[0.0575]	[0.0631]	[0.0604]
SDG13	0.0637***	0.0672***	0.0723***	0.0670***	0.0861***	0.0652***
	[0.0162]	[0.0149]	[0.0163]	[0.0158]	[0.0162]	[0.0162]
INDEP	0.0207**	0.0152*	-0.0136	-0.0028	-0.0249***	-0.0272***
	[0.0086]	[0.0085]	[0.0094]	[0.0085]	[0.0074]	[0.0092]
GDP	0.1571***	0.1715***	0.1951***	0.1809***	0.1912***	0.1668***
	[0.0522]	[0.0541]	[0.0550]	[0.0539]	[0.0511]	[0.0534]
Constant	0.2219***	0.2417***	0.1516**	0.1743***	0.1332**	0.1450**
	[0.0657]	[0.0613]	[0.0704]	[0.0643]	[0.0666]	[0.0651]
Observations	3,077	3,077	3,077	3,077	3,077	3,077
Number of firms	260	260	260	260	260	260
Country Dummies	YES	YES	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES	YES	YES
Hansen Test	195.7	213.5	202.6	206.8	217.7	211.2
Sig. Hansen	0.995	0.950	0.986	0.976	0.924	0.961
AR2	1.331	1.458	1.389	1.572	1.458	1.559
Sig. AR2	0.183	0.145	0.165	0.116	0.145	0.119

Note: Definitions of the variables are presented in Table 1. The standard errors are indicated in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

First, we estimate each firm's daily stock returns and yearly standard deviations. We then divide firms into two groups using the industry-yearly median of volatility and create a dummy variable that takes a value of 1 for firms with volatility over the median and 0 otherwise. This new dummy is coded similar to the dummy that originates from the bid-ask spread. The results of H2, shown in Table 7, using price volatility, are very similar to those found in the main analysis, following the same pattern as seen in Table 6.

Following Dhaliwal et al. (2014), we use scaled accruals as a second alternative proxy for information asymmetry, calculated as follows.

$$ACCRUAL_{it} = \frac{\Delta CA_{it} - \Delta CL_{it} - \Delta CASH_{it} + \Delta STD_{it} - DEP_{it} + \Delta TP_{it}}{TA_{it-1}} \quad (4)$$

Where ΔCA is the variation of current assets, ΔCL is the variation of current liabilities, ΔCASH is the variation of cash, ΔSTD is the variation of the current portion of long-term debt included in total current liabilities, DEP is the depreciation and amortization expense, ΔTP is the variation of payable income taxes, and TA is the one-year lag of total assets.

Similar to what we did with the bid-ask spread and price volatility, we estimate accruals as a complementary accounting-based measure following previous literature (Armstrong et al., 2011; Akins et al., 2012). We then divide firms into two groups using the industry-yearly median of these accruals, creating a dummy variable that takes the value of 1 for firms with accruals over the median and 0 otherwise. Therefore, this new dummy is coded in the same manner as the previous dummies. The results for H2 shown in Table 8 using accruals are similar to those obtained in the main analysis, following the same pattern as seen in Table 6.

Table 8. Replication of previous results with accruals as an IA proxy

	CSR		GRI		ENV	
	(1)	(2)	(3)	(4)	(5)	(6)
MAT_{t-1}	0.4131***	0.4118***	0.4137***	0.4321***	0.4014***	0.3895***
	[0.0145]	[0.0148]	[0.0180]	[0.0173]	[0.0180]	[0.0189]
CEP	0.0765***	0.0711***	0.0994***	0.0753***	0.1201***	0.1265***
	[0.0182]	[0.0177]	[0.0195]	[0.0171]	[0.0193]	[0.0178]
CEP*CSR	0.0468*	-0.0667***				

	[0.0239]	[0.0228]				
CEP*CSR*HIGH_IA	-0.1278***					
	[0.0193]					
CEP*CSR*LOW_IA		0.1409***				
		[0.0172]				
CEP*GRI			0.0890***	-0.0453**		
			[0.0219]	[0.0195]		
CEP*GRI*HIGH_IA			-0.1534***			
			[0.0242]			
CEP*GRI*LOW_IA				0.1309***		
				[0.0196]		
CEP*ENV					-0.0639***	-0.1244***
					[0.0215]	[0.0195]
CEP*ENV*HIGH_IA					-0.0648***	
					[0.0231]	
CEP*ENV*LOW_IA						0.0861***
						[0.0213]
TANG	-0.0551**	-0.0736***	-0.0673**	-0.1138***	0.0102	-0.0156
	[0.0232]	[0.0245]	[0.0261]	[0.0307]	[0.0282]	[0.0306]
MTB	0.0047***	0.0037***	0.0031***	0.0005	0.0036***	0.0027**
	[0.0011]	[0.0011]	[0.0012]	[0.0012]	[0.0012]	[0.0012]
LIQ	0.0378***	0.0361***	0.0415***	0.0397***	0.0505***	0.0451***
	[0.0045]	[0.0043]	[0.0052]	[0.0052]	[0.0053]	[0.0057]
SIZE	0.0113***	0.0066**	0.0094***	0.0043	0.0142***	0.0105***
	[0.0030]	[0.0026]	[0.0031]	[0.0031]	[0.0032]	[0.0031]
PROF	0.2873***	0.3396***	0.4439***	0.4640***	0.2681***	0.3045***
	[0.0551]	[0.0573]	[0.0660]	[0.0693]	[0.0643]	[0.0656]
SDG13	0.0472***	0.0331*	0.0689***	0.0822***	0.0760***	0.0839***
	[0.0168]	[0.0173]	[0.0159]	[0.0189]	[0.0175]	[0.0176]
INDEP	0.0059	0.0109	0.0092	0.0102	-0.0225***	-0.0142*
	[0.0076]	[0.0076]	[0.0077]	[0.0088]	[0.0082]	[0.0085]
GDP	0.2019***	0.2223***	0.1594***	0.1902***	0.2106***	0.2554***
	[0.0540]	[0.0572]	[0.0550]	[0.0571]	[0.0529]	[0.0554]
Constant	0.1213*	0.2293***	0.1560**	0.2744***	0.0538	0.1622**
	[0.0690]	[0.0588]	[0.0713]	[0.0702]	[0.0751]	[0.0730]
Observations	3,077	3,077	3,077	3,077	3,077	3,077
Number of firms	260	260	260	260	260	260
Country Dummies	YES	YES	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES	YES	YES
Hansen Test	202.5	198.3	210.3	204.8	214.9	212
Sig. Hansen	0.984	0.991	0.961	0.979	0.937	0.953
AR2	1.641	1.675	1.579	1.652	1.505	1.476
Sig. AR2	0.101	0.0939	0.114	0.0985	0.132	0.140

Note: Definitions of the variables are presented in Table 1. The standard errors are indicated in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Additionally, we check the robustness of our results by including a different industrial control variable. Previous studies have found that firms operating in the same industry could develop similar environmental strategies because of social expectations as well as standardized institutional practices (Gallego-Álvarez & Pucheta-Martínez, 2020). Therefore, carbon emission levels and their effects on a firm's financial performance can

depend on the industry in which the firm operates. To analyze this industry effect, we follow Young & Marais (2012) and Gallego-Álvarez & Pucheta-Martínez (2020) and divide firms according to their impact on stakeholders, building a dummy variable that takes a value of 1 if the firm operates in an industry considered to have high social and environmental impact and a value of 0 otherwise. Finally, following Fernández-Cuesta et al. (2019), we use the variation in sales to control for whether carbon performance improvements stem from increased efficiency or a reduction in a firm's activity. To do so, we include a new dummy variable in our model, DSALES, which takes the value of 1 when a firm's sales grow and 0 otherwise. These additional analyses (untabulated results) confirm the robustness of the results.

5. CONCLUSION

Carbon disclosure influences strategic financing decisions through both managers' use of information asymmetry and firms' stakeholders' use of the information issued. Information reliability is important because financial institutions assess environmental risks that affect their willingness to provide capital and the conditions offered. Specifically, to understand and verify the strong and positive relationship between carbon performance and debt maturity, this study advances research by adding the moderating role of the disclosure of non-financial information in the context of market information asymmetry, which can mitigate or intensify the baseline relationship.

Our results indicate that carbon performance has a positive effect on debt maturity and that this effect seems to increase when firms disclose voluntarily structured non-financial information (GRI). When this information is not structured (CSR and environmental reports), its release has no additional positive effect on the baseline relationship. Information asymmetry moderates this relationship. Thus, disclosing three types of information, namely CSR information, non-financial information following GRI principles, and specific environmental information, mitigates the positive effect of carbon performance on debt maturity in high information asymmetry contexts. Since our sample consists of firms operating under the ETS scheme, a high level of public scrutiny can be expected, and this negative effect is consistent with pecking order theory, as favorable private information on carbon performance makes long-term debt less preferable

considering the undervaluation of a firm's securities and worse credit terms. Conversely, disclosing the three types of information strengthens carbon performers' abilities to obtain long-term debt when firms operate in contexts with low information asymmetry. It is worth noting that voluntarily reporting specific environmental information shows worse behavior, resulting in a negative impact on the relationship between carbon performance and debt maturity, especially in the context of high information asymmetry. The strong positive impact of carbon performance (mandatory information) and the strong negative impact of voluntary environmental information (strengthened in high-asymmetry contexts and only weakly offset in low-asymmetry contexts) suggests that costly voluntary environmental reports are redundant with respect to the mandatory data on carbon performance.

In summary, the results show a strong positive effect of GRI reporting on carbon performers' debt maturity, which is consistent with the usefulness and reliability of structured information. Furthermore, when a firm's information asymmetry is added to the analysis, the effect of environmental disclosures on the relationship between long-term debt and carbon performance shows a clear pattern according to the positive effect of the reliability of new data and the offsetting effect of information asymmetry on long-term debt.

Our contribution to the scarce research on the effect of environmental performance on capital structure is the incorporation of the carbon disclosure and information asymmetry perspectives to explain the relationship between debt maturity and carbon emissions. Our empirical evidence helps delimit confidence in carbon disclosure reports when evaluating firms' environmental and financial strategies.

The results indicate that carbon performers benefit from disclosing voluntary non-financial information in low information asymmetry contexts in order to obtain longer debt maturity. Furthermore, structured voluntary non-financial information has a stronger effect. This could be related to the release of useful and reliable information that reduces information asymmetries, to gain/maintain legitimacy and improve the relationship between firms and their stakeholders. By contrast, in high-asymmetry contexts, voluntary information does not help carbon performers obtain additional debt maturity, suggesting a lack of confidence, especially when voluntary information is not

structured, and environmental information could be redundant with the mandatory disclosure of emissions.

The implications for managers are derived as well-designed disclosure of environmental decisions and strategies is crucial for them to manage a firm's public image of its environmental profile (Cormier et al., 2005). The reliability of firms' environmental disclosures is relevant for stakeholders who must calibrate the inherent uncertainties of green investments and, specifically, for creditors who need to adapt their financing strategies and requirements. According to our results, creditors and other stakeholders should assess the reliability by paying attention to the format of the voluntary information issued and to the context of information asymmetry detected by the market. The results of this study will be of interest to policymakers when assessing the implementation of their environmental policies and to regulatory agencies in charge of regulating the disclosure of precise and consistent information.

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