What are the drivers of corporates' climate transparency? Evidence from the S&P 1200 index

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A B S T R A C T

Climate transparency through firms' disclosures is often considered a prerequisite for the redirection of investments toward low-carbon economy. In order to provide effective incentives to improve this transparency, it is therefore crucial to identify its drivers. In this paper, we investigate the determinants of two stages of climate transparency: i) the likelihood of responding to the CDP questionnaire; and ii) the extent to which companies comply with the TCFD recommendations. Using a global sample of 571 firms over the period 2020–2021, we estimate a Two-Part Fractional Response Model. First, the results confirm the relevance of considering two stages of climate transparency as the drivers that explain the first stage differ from those explaining the second. We find evidence that variables related to environmental/climate performance and commitment are good predictors of firms' transparency regarding climate risks and opportunities. Our results show that climate transparency is strongly influenced by governance mechanism variables (apart from gender diversity). We also highlight that regulatory factors only impact the second stage of climate transparency.

1. Introduction

For more than twenty years, sustainable reporting has been constantly developing, representing an important evolution of the transparency expected by investors. Corporates' disclosures other than those presenting accounting and financial information have been generally used as a method to mitigate risks regarding environmental, social and governance issues. Their increasing importance stems from a new approach to firms, which are called upon to be vectors of a more sustainable economy in line with the concept of Corporate Social Responsibility (CSR). This last issue highlights the fact that companies can no longer be considered only as legal entities intended to generate returns on their shareholders' contributions. Consequently, this new

corporate perspective necessarily leads to a reinforcement of the transparency expected from them. This applies in particular to transparency regarding climate risks and opportunities (CROs), an environmental issue subcategory that until now has been neglected in sustainable reference systems. A distinction between transparency[1] and disclosure is useful: while disclosure may be the provision of information, transparency requires that this information reaches the market and is correctly interpreted and used by market players. It follows that improving disclosure does not necessarily improve the transparency of the financial system (Le Quang, 2019; Nielsen and Madsen, 2009).[2] Thus, to be effective, climate-related disclosures should be clear, comprehensive, meaningful to users, consistent over time, and comparable (Crockett, 2002). Transparency may be defined as a process that

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[1] "For a given level of disclosure, transparency depends on investors' information processing capability, behavioral biases, and information needs. Thus, disclosure is a necessary but not a sufficient condition for transparency in the information transmission process." (Freixas and Laux, 2012).

[2] The transition from disclosure to transparency faces many obstacles. There is a cost of processing information; particularly, this applies to providing reliable information to issuers and collecting and interpreting it on the investor side.

involves different stages, that is, similar to a continuum, depending on the nature and characteristics of the corresponding disclosures. These stages can range from no transparency with no disclosures to the most complete transparency that is possible through comparable, relevant and reliable disclosures – standardized disclosures.

Climate transparency can be viewed as a tool for addressing global change issues because it is a prerequisite for the redirection of investments—both those of companies or investors—toward sectors of activity that are more respectful of the environment and the development of these sectors (Poole, 2022). Because it reduces information asymmetry, climate transparency contributes to changing the investment behavior of economic actors to support less carbon-intensive activities. This causal link between transparency and allocation behavior is based on the theory of efficient financial markets, according to which disclosures are intended to enable market participants to make more informed decisions about climate risks. Climate transparency helps build stakeholder confidence in companies (accurate and reliable picture of their financial condition and compliance with laws, regulations, etc.). It also helps to guide investment choices and creates a well-informed market, a requirement for improving the efficiency of the financial system. Conversely, a lack of information limits companies' understanding of these risks and their ability to take action to move toward a low-carbon economy.

Despite an awareness of CROs, there is still a lack of transparency that limits the understanding and therefore the actions of companies and investors. One of the first attempts to improve climate transparency was initiated in 2000 by the Carbon Disclosure Project (CDP), a UK-based nonprofit organization that collects information, through a questionnaire, on how companies are addressing climate change.[3] The CDP database is considered a reference for nonfinancial information on the environment and climate and covers half of the world's market capitalization. While it provides an incentive for companies to disclose information about their CROs, the CDP questionnaire is not prescriptive, as no question is binding. Thus, answering the CDP questionnaire can only be considered the first stage toward climate transparency.

In 2015, during COP 21, the Financial Stability Board (FSB) launched the Task Force on Climate-related Financial Disclosures (TCFD) to establish recommendations for voluntary corporate reporting on the financial implications of climate change. According to Chenet et al. (2021), improvement in transparency and information sharing lies at the center of the TCFD framework, which is the major international policy effort by financial regulators to meet the challenge of climate-related financial risks. Specifically, the recommendations encourage all corporations and financial entities to provide information to stakeholders on CROs regarding 4 subdomains: governance, strategy, risk management, and metrics and targets. More precisely, the disclosures likely to meet TCFD expectations are quantified information on the financial impacts of climate risks, such as data related to investments in the low-carbon sector, environmental expenditures or provisions, quantified emission limitation targets over horizons or relevant emissions related to Scope 3 (Demaria and Rigot, 2021). In this sense, the TCFD attempts to link financial and nonfinancial information by requiring companies to present the financial impact of CROs on their business plan and financing plan in annual reports. The final aim is to improve financial transparency regarding the impact of climate risks (via clear, comparable and consistent disclosures) on companies with the goal of changing their investment behaviors within an increasingly carbon-constrained economy.

The TCFD recommendations have received increasing support since 2015, such as the G20 and the European Commission, and they have become a global reporting benchmark for climate risks[4] (although not binding). This success explains why the latter have been included in legislative proposals (European Commission, 2019; United Kingdom Government, 2019); moreover, in early 2022, the SEC issued a proposed rule called "The Enhancement and Standardization of Climate-Related Disclosures for Investors" based on the TCFD's recommendations SEC (2022). In January 2023, more than 4000 companies in 101 countries supported this initiative. Amar et al. (2022) developed an index to assess the extent to which companies are incorporating the TCFD recommendations, the Climate Risks and Opportunities Index (CRORI). A CRORI of 1 can be interpreted as perfect compliance with the TCFD recommendations. Given the level of detail required by the TCFD, this last stage can be considered more advanced in terms of transparency regarding CROs.

Considering the importance of this topic, the academic world has begun to focus on this new area of research, which is voluntary climate disclosure and the application of TCFD recommendations. From this perspective, this paper aims to better understand firms' climate transparency and its determinants regarding CROs. More specifically, we focus on two stages of climate transparency: i) the likelihood of responding to the CDP questionnaire and ii) the extent to which companies comply with the TCFD recommendations. To answer this research question, we rely on the theory of legitimacy and agency theory, which allow us to formulate four hypotheses. At the empirical level, we estimate a 2-part fractional response model to analyze the two stages of transparency above for a sample of 571 international companies over the period 2020–2021. In addition, to consider the heterogeneity of a global sample, we refine our analysis by discriminating firms based on, first, their industry and, second, their geographic area.

We find evidence that different determinants explain the two stages of transparency, demonstrating the relevance of a 2-step analysis. We find that variables related to environmental/climate performance and commitment are good predictors of firms' transparency regarding CROs. Similarly, we find that climate transparency is strongly influenced by governance mechanism variables (apart from gender diversity). Interestingly, we find that regulatory factors only impact the second stage of climate transparency.

The contribution of this paper is fourfold. First, from an empirical point of view, this paper is the first to consider climate transparency as a process that involves different stages, such as a continuum, depending on the nature and characteristics of the corresponding disclosures. Second, while research on climate reporting has developed in recent years and very recently on the TCFD, this study analyzes the determinants of climate transparency on a large international sample (27 countries). Third, we contribute to the literature by confirming the relevance of legitimacy theory for explaining firms' climate transparency. To our knowledge, this is the first paper to demonstrate the relationship between climate transparency and environmental performance and management system. Similarly, the explanatory power of agency theory, through governance mechanisms and the institutional structure of shareholding, is confirmed. Finally, this paper has managerial contributions for firms. It highlights that the environmental management system (EMS) and the presence of a sustainability committee have a positive effect on improving climate transparency. These optional systems should be developed in companies to increase climate transparency in CROs. The results of this global study may be useful for policy makers to improve financial transparency through country-

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[3] To date, the CDP represents the most important database about the business climate-related responses related to risks and opportunities, climate-related strategies and carbon accounting of thousands of the world's largest firms; therefore, the CDP has become a common source of data for business studies on climate change (Gasbarro et al., 2017).

[4] There is today a willingness to recast climate change as a strategic and financial risk and no longer view it as a peripheral ethical issue. Indeed, they view climate disclosure requirements as climate polices (Gallagher and Xuan, 2018) with the aim of mobilizing financing for climate-related objectives (including the acceleration of decarbonization and improvements in adaptation and resilience to climate change impacts).

specific regulations.

The remainder of the paper is organized as follows. Section 2 presents the literature review and the research hypotheses. Section 3 displays the data and methodology. Section 4 assesses the main drivers of international corporations' climate disclosures. Section 5 discusses and concludes the paper.

2. Theoretical foundation and hypothesis development

This review of the literature will first be devoted to a brief overview of research dedicated to TCFD voluntary climate disclosure and then to the theories that allow us to understand the rationale for voluntary climate disclosure.

2.1. Previous research on TCFD climate disclosures

Research on voluntary climate disclosure has long focused on firms' disclosure of their GHG emissions reduction policies. It emerges from various studies that many companies provide the minimum information required to avoid scrutiny but remain rather fuzzy about their amount of emissions (Stanny, 2013; Tang and Demeritt, 2018; Velte et al., 2020). Research dedicated to climate disclosure has truly taken off with the publication of the TCFD recommendations in 2017. Previously, research has focused more on environmental reporting using general frameworks such as the GRI or Integrated Reporting (Gerwanski, 2020; Latridis, 2013; Reverte, 2009). Recently, many authors have studied the application of TCFD recommendations on samples of large companies and conclude that since 2017, real progress has been made in terms of climate risk and opportunity disclosures. However, there are still many areas for improvement related, for instance, to climate strategy, scenario analysis, forward-looking information or the remuneration of directors (Braasch and Velte, 2023; Chenet et al., 2021; Cosma et al., 2022; David and Giordano-Spring, 2022; Demaria and Rigot, 2021; Friedrich et al., 2022; Gelmini and Vola, 2022; Hayashi, 2020; Moreno and Caminero, 2020). This leads Bingler et al. (2022) to estimate that firms' TCFD support is mostly cheap talk and that firms cherry-pick to report primarily nonmaterial climate risk information. In the same way, Di Marco et al. (2022) conduct a quantitative and qualitative study and show that firms' disclosure practices fall short of the TCFD's disclosure requirements to a great extent. Aware of the stakes of these new recommendations, O'Dwyer and Unerman (2020) propose 26 lines of research on the contributions of the TCFD to the consideration of climate risks and opportunities.

Another area of research is based on the identification of the determinants of a more or less good level of disclosure of climate or carbon disclosure. It appears quite clear that the country in which the company is located is an essential factor in the transparency strategy of companies (Backman et al., 2017; Reid and Toffel, 2009), the presence of a CSR committee (Cosma et al., 2022), the size of the firm (Loew et al., 2020), and media visibility (Schröder, 2021). It is noticeable that in current work on the TCFD, the determinants related to environmental performance are little studied. Indeed, only Ding et al. (2023) study how the level of CO_2 emissions affects voluntary climate-related disclosure based on TCFD principles. They show that firms with higher levels of carbon emissions disclose more climate-related information. This relationship is stronger for firms belonging to carbon-intensive industries, such as energy, materials, and utilities.

Most of these studies are grounded in two main theories: legitimacy and agency. Cotter et al. (2011) highlight that these two theories are most often used to explain this type of disclosure. First, legitimacy theory appears to be one of the most relevant to explain the voluntary release of nonfinancial information insofar as firms are trying to convey a message to several types of stakeholders emphasizing that they are conforming to their expectations and persuading them about their performance to maintain their legitimacy. Agency theory allows us to understand how climate information can be seen as a means of solving the problem of informational asymmetry.

2.2. Legitimacy theory

The main concept behind this theory is defined by Suchman (1995) as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions. In order to assert their legitimacy, companies must act within the limits that society identifies as socially acceptable". Legitimacy theory makes it possible to understand companies' practices by analyzing managers' strategic choices to meet society's expectations (Deegan et al., 2002). This point of view is explained by the fact that various stakeholders perceive legitimate organizations not only as more worthy than others but also as more meaningful, more predictable and more trustworthy (Suchman, 1995). Firms must be considered legitimate by markets on several levels, namely, not only in terms of commercial and financial strategy but also in terms of the way they take the environment into account in their activities. With regard to environmental disclosure, Depoers and Jérôme (2017) consider that legitimacy theory places organizations within a sociopolitical framework and that environmental disclosure is a means for managers to establish and maintain a firm's legitimacy. In recent years, the disclosure of information related to climate change has been required by investors, policymakers, customers, and suppliers, and climate-related activities have gained relevance in society overall (Kouloukoui et al., 2019). This has led to climate disclosures constituting a communication channel that enhances the legitimacy of a firm from the perspective of society (Velte et al., 2020). From this point of view, companies are required to disclose climate information according to the image they want to project to the market.

To explain why a firm discloses information in general and environmental or climate information in particular, legitimacy theory suggests that more visible companies (such as polluting firms or large companies) attract more attention from different stakeholders and thus are more prone to social and political pressures to enhance their environmental disclosures and thus maintain their legitimacy (Hahn et al., 2015; Hassan and Romilly, 2018; Marco-Fondevila and Álvarez-Etxe-berría, 2023). It assumes that particularly poorly performing companies use sustainability disclosures as a legitimation tactic to influence public perceptions regarding their sustainability performance (Braasch and Velte, 2023; Cho et al., 2012; Deegan et al., 2002; Ding et al., 2023; O'Donovan, 2002; Park et al., 2023). Moreover, climate disclosure can be seen as a voluntary tool to reduce legitimacy gaps for firms that have weak climate performance (Qian and Schaltegger, 2017) and as a new tool to increase legitimacy by diverting the stockholders' attention from actual performance (Stanny, 2013).

Climate performance can be understood from two perspectives: downstream via the level of a firm's GHG emissions and upstream via the implementation of an EMS to monitor and improve a firm's climate performance. Relying on legitimacy theory, we assume that firms with weak climate performance are more likely to implement climate transparency strategies and disclose more information on climate risks and opportunities in compliance with TCFD recommendations. Therefore, our first hypothesis is as follows:

Hypothesis 1. There is a negative relation between environmental/climate performance and climate disclosure.

2.3. Agency theory

The agency relationship is at the heart of the problems related to corporate governance faced in large corporations, particularly those arising between the owners of capital, who are shareholders (principal),

and managers (agents). Top management, who is directly involved in the decision-making process, has more information on company strategies than any other stakeholder (including investors and shareholders). Managers are highly motivated to pursue their own benefits and opportunities in the short term. To limit such risks, companies must be able to build effective monitoring and incentive systems. Therefore, according to agency theory, a firm's board of directors has the power and legitimacy to exert control over its managers and ensure that they act in the best interests of the firm's shareholders and other stakeholders (Fama and Jensen, 1983; Jensen and Meckling, 1976). Large companies can follow "best practices" in terms of board diversity via diverse profiles representing shareholders to effectively and autonomously exercise their power of control over decisions. Hypotheses 2, 3 and 4 are derived from this theoretical framework.

Regarding climate change issues specifically, agency theory posits that the board is responsible for monitoring management's sustainable policies and strategies to the extent that management may be reluctant to invest in sustainable areas because such investment provides no immediate benefit (Bae et al., 2018). Because external directors are subject to a lesser degree of pressure from shareholders and managers than internal directors, board independence is positively associated with sustainability reporting (Hussain et al., 2016). Independent directors are incentivized to establish and maintain their reputation as professional experts who effectively monitor managers and look after shareholders' best interests (Fama and Jensen, 1983). Furthermore, independent directors broaden sensitivity to social demands because they inhibit a focus on short-term results (Yunus et al., 2016). The number of independent directors on a board contributes to its diversification, as does the number of women on the board. Some studies suggest several factors supporting a positive relationship between board gender diversity and company disclosures. First, appointing more female directors enhances the diversity of opinions in board discussions (Barako and Brown, 2008), thereby ensuring the consideration of a wider range of perspectives in the decision-making process and improving board communication (Bear et al., 2010). Second, firms with a diverse board possess broader knowledge with which to identify the best strategies to manage potential conflicts among stakeholders (Harjoto et al., 2015). Hence, the presence of female directors may provide a better assessment of the needs of diverse stakeholders, which, in turn, enables a firm to make better decisions (Bear et al., 2010). Otherwise, a board committee focused on environmental/sustainable/CSR issues ensures both monitoring and advice on the company's CSR policy and strategy. They are more concerned with their firm's environmental performance because they understand that it influences perceptions of their own performance and reputation. Therefore, it will provide better management of environmental and social issues (Dixon-Fowler et al., 2017), enhance awareness of the potential impacts of social and environmental risks on the company's competitive advantage and implement strategies to address those risks. For instance, Cordova et al. (2021) consider that the presence of a CSR committee is necessary to increase the transparency of information and to face the challenges posed by CROs. Thus, we expect that diverse boards are more engaged in the proactive management of climate risks via increased disclosure.

Hypothesis 2. There is a positive relation between governance mechanisms and climate disclosure.

In addition to the composition of boards of directors, an important element in governance is the ownership structure (Fama and Jensen, 1983). Large corporations have different shareholders that encompass many forms, with foreign, public, family or institutional owners. For the past four decades, these last ones, including pension funds and mutual funds, have represented significant shareholders with strong incentives to monitor the firms in which they own stock to the extent that they hold the highest percentage ownership and voting rights (Demsetz and Lehn, 1985). Indeed, institutional investors are active on the board because they have to create value for their own shareholders. As a result, they are

very concerned about the investment risk and return trade-off in the long run. This implies considering environmental issues by committing to sustainable investment and sustainable development projects. Using voting rights, institutional investors can influence management to disclose more sustainability information. The objective is to send a signal to the market about their management in the strategic decision-making process regarding economic, social and environmental issues. The prior literature indicates that shareholder pressure is one of the main drivers of increased sustainability reporting (Deegan and Blomquist, 2006). Some studies show a positive relationship between institutional ownership and sustainable disclosure related to the long-term nature of the investment process. (Khan et al., 2013; Won-Yong et al., 2011). Therefore, our third hypothesis is as follows:

Hypothesis 3. There is a positive relation between institutional ownership and climate disclosure.

In addition to the governance mechanisms, another determinant addressed in the literature is regulation implemented by the State. Even if regulatory requirements may be different by country and sector, the aim is to incentivize companies in a more or less restrictive manner to enhance their accountability processes (Lombardi et al., 2022). Indeed, if we consider the agency relationship between the State and companies, the State has less information than firms on the nature and degree of their commitment to the fight against climate change. As a result, the State only imperfectly observes firms' behavior in their efforts to reach the GHG emission reduction targets to which the State has committed itself; this reveals a lack of alignment of interests between these two actors. The first form of firms' commitment is their disclosure on how their activities have an environmental impact and how they take climate risks into account in their strategies. To align the interests of businesses with those of the State with respect to climate objectives, the State implements more or less restrictive measures in the form of regulatory requirements or incentives (Cohen, 2000; Reid and Toffel, 2009). Such disclosures reduce information asymmetries. As underlined by Principale and Pizzi (2023), companies operating in countries with more stringent environmental regulations are subject to greater pressure regarding their environmental commitment, including carbon emission reduction. More precisely, these components of regulations may influence companies' climate disclosure behavior since they contribute to the generation of social expectations, which exert pressure on companies to voluntarily disclose climate information (Mateo-Márquez et al., 2021). Several studies highlight the positive effect of a country's regulations on the level of voluntary disclosure of climate information (David and Giordano-Spring, 2022; Grauel and Gotthardt, 2016; Mateo-Márquez et al., 2021). Such disclosures reduce information asymmetries. Therefore, our fourth hypothesis is the following:

Hypothesis 4. There is a positive relation between environmental/climate regulations and climate disclosure.

3. Data and descriptive statistics

3.1. Sample and dependent variables

The analysis focuses on large-cap firms, as our sample consists of 571 firms[5] from the S&P 1200 index. This sample has several advantages. First, it avoids sample bias since it includes all companies that meet the eligibility criteria defined by Standard & Poor's. Second, it provides efficient exposure to the global equity market, as the S&P 1200 index captures approximately 70% of *global* market *capitalization*. Third, the sample is evenly distributed across geographic areas and covers all

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[5] We initially started with all 1223 companies from the S&P 1200, but some companies had to be removed from the sample due to a lack of available data for the 2 years.

Table 1

Evolution of the number of firms that responded to the CDP questionnaire considering high and low-stakes industries.

Sector	No CDP answer	CDP answer	Total
2020	**223 (39.1%)**	**348 (60.9%)**	**571**
High-stakes	*124 (39.5%)*	*190 (60.5%)*	*314*
Low-stakes	*99 (38.5%)*	*158 (61.5%)*	*257*
2021	**182 (31.9%)**	**389 (68.1%)**	**571**
High-stakes	*105 (33.4%)*	*209 (66.6%)*	*314*
Low-stakes	*77 (33%)*	*180 (70.0%)*	*257*

Relying on the TCFD recommendations, high-stakes sectors include the following sectors: finance, energy, transport, food, and materials & buildings; and low-stakes sectors include all others.

industries, allowing for subanalyses by region and industry.

Regarding the time period, the analysis is performed over the period 2020–2021 due to both the characteristics of the dependent variable and the availability of explanatory variables. In regard to the second stage of climate transparency, the dependent variable is an index of compliance with TCFD recommendations, which were released in 2017. It was not possible to perform the analysis on a period prior to 2018. In addition, because the study includes company-specific data such as CO_2 emissions, the sample period is highly dependent on the availability of these data. Unfortunately, for 2018 and 2019, the number of missing values, especially for CO_2 emissions, did not allow us to perform our analysis over these years.

As explained in the introduction, transparency may be understood as a process that involves different stages depending on the nature and characteristics of the disclosures. That is why we use 2 measures to assess the examined corporations' climate disclosure practices.

The first stage of climate transparency is proxied by the dependent variable, which denotes whether a firm answered the CDP questionnaire: it takes the value of 1 if the focal firm answered the CDP questionnaire and 0 otherwise.

For the second stage of climate transparency, we use the CRORI, which is a composite index ranging from 0 to 1, assessing the level of compliance with the TCFD recommendations. Specifically, the TCFD lists a set of items that must be disclosed by a company to be considered transparent about its CROs. The CRORI indicates the extent to which these items are disclosed. In the original paper of Amar et al. (2022), the CRORI is computed by checking whether the TCFD items are present in the companies' annual reports. To automate data collection for a large sample size, the CRORI list of 24 questions[6] is matched to the CDP survey questions on the application of the TCFD and the Refinitiv database. Notably, the CRORI can only be calculated if a firm has responded to the CDP survey.

3.2. Descriptive statistics of the dependent variables

Table 1 and Table 2 show the number and proportion of companies that responded to the CDP questionnaire in 2020 and 2021, respectively, discriminating by industry (high-stakes/low-stakes) and region (Anglo-Saxon countries,[7] Europe, Asia[8] and South America).

Table 1 shows that there is a slight increase in firms responding to the CDP questionnaire over the period, as in 2020 (and 2021), 348 firms (resp. 389) and 223 (resp. 182) did not. In 2020, as in 2021, a similar proportion of companies in high and low-stakes sectors responded to the CDP questionnaire. On the basis of these descriptive statistics, it does not

Table 2

Evolution of the number of firms that responded to the CDP questionnaire by geographic area.

Geographic area	No CDP answer	CDP answer	Total
2020	**223 (39%)**	**348 (61%)**	**571**
Anglo-Saxon Countries	*112 (42%)*	*154 (58%)*	*266*
Europe	*69 (36%)*	*123 (64%)*	*192*
Asia	*22 (24%)*	*68 (76%)*	*90*
South America	*20 (87%)*	*3 (13%)*	*23*
2021	**182 (32%)**	**389 (68%)**	**571**
Anglo-Saxon Countries	*90 (34%)*	*176 (66%)*	*266*
Europe	*60 (31%)*	*132 (69%)*	*192*
Asia	*14 (16%)*	*76 (84%)*	*90*
South America	*18 (78%)*	*5 (22%)*	*23*

seem that belonging to high and low-stakes industries tends to influence the likelihood of responding to the CDP questionnaire.

Table 2 shows that the sample is mostly composed of firms originating from Anglo-Saxon countries (266) and Europe (192). In the sample, Asian firms answer the CDP questionnaire most frequently (76% in 2020 and 84% in 2021). In 2020, the proportion of firms that responded to the CDP questionnaire in Europe was higher than that in Anglo-Saxon countries (64% versus 58%). In 2021, this gap decreases, as the proportion of companies having answered the CDP questionnaire is 66% in Anglo-Saxon countries and 69% in European countries. It should be noted that it is not possible to specifically analyze South American companies given their small number in the sample (23 firms). Overall, these statistics show heterogeneity between geographical areas regarding the likelihood of responding to the CDP questionnaire.

Table 3 displays the average CRORI in 2020 and 2021 discriminating firms by geographic area and by industries with high and low stakes. It shows that regardless of the geographic area, the average CRORI increases over the period. Moreover, Asian companies have the highest average CRORI (0.858 in 2020 and 0.871 in 2021). This finding may be explained by the large number of Japanese companies in the sample (148), which have strong incentives to comply with the TCFD recommendations.[9] In contrast, Anglo-Saxon firms display a lower average CRORI than the average CRORI of the sample (0.775 vs. 0.804 in 2020 and 0.803 vs. 0.830 in 2021). In addition, we find that firms operating in industries with high environmental stakes display, on average, a higher CRORI (0.811 in 2020 and 0.838 in 2021) than firms operating in industries with low environmental stakes.

Overall, these statistics show heterogeneity between geographical areas as well as between sectors of activity regarding compliance with TCFD recommendations.

Table 3

Average CRORI by geographic area and by high and low-stakes industries.

	2020	2021
Anglo-Saxon Countries	0.775	0.803
Asia	0.858	0.871
Europe	0.811	0.840
South America	0.745	0.860
High-stakes	0.811	0.838
Low-stakes	0.795	0.820
All	0.804	0.830

The CRORI is a composite index developed by Amar et al. (2022), assessing the level of firms' compliance with the TCFD recommendations.

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[6] The list of questions to calculate the CRORI is available upon request.

[7] Anglo-Saxon Countries can be defined as the countries of the world in which the English language and cultural values predominate (USA, Canada, UK, Australia).

[8] It is important to note that in this sample, most Asian firms are Japanese firms (82 Japanese firms over 90 Asian firms).

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[9] Japan has in particular set up the TCFD Consortium which produces guidance that has been developed to enhance disclosure by companies in line with the TCFD recommendations.

3.3. Explanatory variables

We distinguish between 3 categories of independent variables. The first type of variable is related to environmental and climate performance. To test the link between these variables and climate disclosure (hypothesis 1), we include 4 variables denoting the environmental performance of companies. We use i) the level of each firm's CO_2 *Emissions,* ii) the number of environmental controversies (*Env. Controv.*) linked to the environmental impact of each firm's operations on natural resources or local communities.[10] iii) a dummy variable denoting whether each company is *ISO 14000* certified and iv) a dummy variable if the firm endorsed *Sustainable Goal 13* (SDG 13), which is related to climate change.

The second type of variable addresses corporate governance mechanisms. To test hypothesis 2, we retain 4 explanatory variables: i) *Independ. Board,* which indicates the percentage of independent board members, ii) *Gender Div.* which indicates the share of female directors, iii) *CSR Ext. Audit,* which equals 1 if the company has implemented a CSR external audit, and iv) *CSR Committee*, which indicates the presence of a CSR committee within the firm. To test hypothesis 3, we rely on 1 variable (*Instit. Own.*), which is the proportion of institutional shareholders. The third type of variable is related to the regulatory framework of the state (*Laws & Policies*); namely, we test the relation between climate disclosure and the level of regulation. Following the prior literature, this research controls for firm size (log *Assets*), financial performance with *5Y Tobin* and *CC EPI*, which is the climate change EPI score of the focal country. All these explanatory variables have been collected from Refinitiv, one of the leading data providers, except *Laws&Policies* and *CC EPI*, which have been retrieved from the Climate Change Laws of the World database and the Environmental Performance Index database, respectively (Wolf et al., 2022). Details on the explanatory variables are presented in Table 4.

3.4. Methodology and empirical model

Regarding the second stage of climate transparency, the dependent variable is an index defined and observed only on the standard unit interval (i.e., $0 \leq y \leq 1$), which makes it a fractional variable. It is well-known that linear models are not well-suited for estimating the effects of explanatory variables on fractional dependent variables because the conditional expectation of a variable bounded between 0 and 1 cannot be a linear function of its parameters. In this context, Papke and Wooldridge (1996) proposed the fractional regression model (1P-FRM), which overcomes the limits of linear and Tobit models and specifically addresses dependent variables defined on the unit interval. However, as explained in the introduction, transparency may be understood as a process that involves different stages, depending on the nature and characteristics of the disclosures. In the empirical analysis, it is thus important to estimate a model that allows us to disentangle the decision on the first and second stages of transparency (i.e., firms' decision to respond to the CDP questionnaire and their decision concerning their degree of compliance with TCFD recommendations). The 1P-FRM addresses the fractional nature of the dependent variable, but it does not account correctly for the dual nature of the transparency process. A two-part version of the FRM (2P-FRM) was thus proposed by Ramalho and Silva (2009), and this allows us to separate the stages of the transparency process. The two-part model also allows us to mitigate the endogeneity that would arise if we were exclusively focusing on the second part of the model. This simplification would indeed induce a potential selection bias because the firms that respond to the CDP questionnaire are not necessarily representative of the full universe of firms.

The first decision is modeled as the following binary choice model:

$$y^* = \begin{cases} 0 \text{ if } y = 0 \\ 1 \text{ if } y \in [0,1] \end{cases} \tag{1}$$

and

$$Pr(y^* = (1|x) = E(y^*|x) = F_{P1}(x\beta_{bin})$$

where $F_{P1}()$ is some nonlinear function satisfying $0 \leq F_{P1}() \leq 1$ (such as a logit, probit, log or log function[11]) and $P1$ stands for "Part 1" of the 2P-FRM. This binary model is estimated by maximum likelihood.

The second decision is specified as the following FRM, which explains the level of the CRORI target:

$$E(y|x, y \in [0,1]) = F_{P2}(x\beta_{frac}) \tag{2}$$

where $F_{P1}()$ is some nonlinear function satisfying $0 \leq F_{P2}() \leq 1$ and $P2$ stands for "Part 2" of the 2P-FRM. This fractional part is estimated by Bernouilli-based quasi-maximum likelihood (see Ramalho et al. (2011) for details).

4. Results

4.1. Drivers of climate transparency

Table 5 and Table 6 display the results of the binary and fractional parts of the 2P-FRM (first and second stage of transparency) described by Eq. 1 and Eq. 2, respectively. The same explanatory variables are included in both equations of the model. For both equations, we include the general model with explanatory variables corresponding to the full set of hypotheses in the first column. We then report the estimates of different versions of the model with alternative explanatory variables. In each table, the last column gives the results of the parsimonious model. The reported numbers in Table 5 and Table 6 are average marginal effects. However, since they show single estimates, it is necessary to also propose a graphical interpretation of the results for continuous variables. Fig. 1 (resp. Fig. 2) give the average predicted probability to respond to the CDP questionnaire (resp. the predicted CRORI) for different values of significant explanatory variables.[12] Estimates are displayed with confidence intervals.

Several insights emerge from the analysis. First, regarding climate and environmental performance variables, the results show a positive and significant relationship between ISO 14000 and both the first and second steps of climate transparency. More precisely, the probability of responding to the CDP increases by 0.088 when the firm is ISO 14000 certified and its CRORI increases by 0.028. These results are in line with those of David and Giordano-Spring (2022), who show that the EMS is a way to reduce vulnerability and exposure to climate risk to the broader transformation of organizations and to improve climate reporting. Moreover, the CRORI of firms that endorsed the SDG 13 guidelines is, on average, 0.028 higher compared to companies that did not. These results are in line with Li et al. (2018) and Ott et al. (2017), indicating that firms that implement climate performance management and monitoring systems are more transparent. In addition, we find that when a firm faced environmental controversies, its probability of responding to the CDP questionnaire decreased by 0.251, showing that the least environmentally performing companies tend to be less transparent. These results do not support H1, according to which there is a negative relation between

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[10] Aerts and Cormier (2009) and Busch and Hoffmann (2011) use a variable that measures media controversies to explain environmental disclosure.

[11] In our analysis, we use a loglog function whose relevance to the alternative specifications has been verified using RESET (Papke and Wooldridge, 1996; Ramalho et al., 2011) and P-tests (Davidson and MacKinnon, 1981) The results are available upon request.

[12] The tables give average effects, which may mask heterogeneity depending on the values taken by the explanatory variables. Their interpretation must therefore be completed by graphical analyses.

Table 4

Description of the explanatory variables.

Variables	Description	Sources	Hypothesis	Expected sign	Previous academic
Environmental and climate performance					
CO_2 Emissions	Natural logarithm of the annual CO_2 emission level of the company in tons	Refinitv	H1	+	Guenther et al. (2015)
Env. Controv.	Dummy variable equal to 1 if the firm has faced environmental controversies the previous year	Refinitv	H1	+	Aerts and Cormier (2009)
ISO 14000	Dummy variable equal to 1 if the company has endorsed ISO 14000 norms and 0 otherwise	Refinitv	H1	−	Ott et al. (2017) Camilleri (2022)
SDG 13	Dummy variable equal to 1 if the company has endorsed the Sustainable Development Goals on climate action and 0 otherwise	Refinitv	H1	−	Yamane and Kaneko (2022)
Governance mechanism					
Independ. Board	Percentage of independent directors on the board	Refinitv	H2	+	Jizi et al. (2014)
Gender Div.	Percentage of female directors	Refinitv	H2	+	Frias-Aceituno et al. (2013) Katmon et al. (2019)
CSR Committee	Dummy variable equal to 1 if the firm has set up a CSR committee and 0 otherwise	Refinitv	H2	+	Cosma et al. (2022) Gelmini and Vola (2022)
CSR Ext. Audit	Dummy variable equal to 1 if the firm has implemented a CSR external audit and 0 otherwise	Refinitv	H2	+	Giannarakis et al. (2017)
Instit. Own.	Percentage ratio of freely traded shares held by institutions to the number of float shares outstanding	Refinitv	H3	+	Safitri and Sri Wahyuningrum (2021)
Regulatory factors					
Laws&Policies	Number of laws and policies related exclusively to climate change	https://climate-laws.org/	H4	+	Original variable
Control variables					
log Assets	Natural logarithm of total assets	Refinitv			Loew et al. (2020)
5Y Tobin	5-year Tobin's Q	Refinitv			Busch and Hoffmann (2011)
CC EPI	Score ranging from 0 to 100 that measures countries' progress to mitigate global climate change	https://Climate Change EPI Score.yale.edu/			Luo and Smith (2019) Caby et al. (2020)

Table 5

Part 1 of the 2P-FRM – Firms' decision to respond to the CDP questionnaire.

	(1)	(2)	(3)	(4)	(5)	(6)
ISO 14000	0.083***	0.0838***	0.0825***	0.082***	0.082***	0.088***
CSR Committee	0.198***	0.199***	0.195***	0.193***	0.195***	0.199***
Env-controversies	−0.249***	−0.248***	−0.252***	−0.252***	−0.251***	−0.251***
Independ. Board	0.002**	0.002**	0.002**	0.002**	0.002**	0.001*
Institutional Share	−0.004	−0.004	−0.004	−0.004	−0.004	−0.005*
Laws&Policies	0.002	0.002	0.002	0.002	0.002	
CSR External Audit	0.039	0.039	0.039	0.041		
Gender Diversity	0.001	0.001	0.001			
CO_2 Emissions	−0.002	−0.002				
SDG 13	0.007					
Log Assets	0.054***	0.054***	0.054***	0.053***	0.054***	0.053***
Tobin 5Y	0.026**	0.026**	0.027**	0.026**	0.027**	0.024**
EPI	0.011***	0.011***	0.011***	0.011***	0.011***	0.012***
N	1142	1142	1142	1142	1142	1142
Log-lik.	−679.948	−679.980	−680.023	−680.133	−680.603	−681.351
AIC	1387.895	1385.961	1384.046	1382.267	1381.206	1380.703
BIC	1458.463	1451.488	1444.533	1437.713	1431.611	1426.068

The coefficients are the marginal effects. The dependent variable is a dummy variable equal to 0/1 if the firm does not/does respond to the CDP questionnaire. Column (1) gives the results of the full model. Column (6) gives the results of the parsimonious model. The other columns give the results of alternative specifications.

* significant at 10%
** significant at 5%
*** significant at 1%.

environmental/climate performance and climate disclosure. In contrast, our results suggest that the level of CO_2 emissions does matter for explaining the CRORI. In Fig. 2b, we see that when firms' CO_2 emissions are low, the predicted CRORI is approximately 0.73, whereas when they are high, the predicted CRORI is approximately 0.85. This result confirms H1 and is consistent with prior studies that show that the most poorly environmentally performing firms (most polluting) disclose the most (Cho and Patten, 2007; Ding et al., 2023; Hassan, 2018; Wedari et al., 2021). The results confirm the duality of legitimacy theory already

identified in previous research. Indeed, while some polluting companies will increase their transparency, particularly by applying the TCFD recommendations, we also observe that virtuous companies will tend to be more transparent at all levels. In other words, depending on the case, the level of transparency may increase for both climate-performing and nonperforming companies to ensure their legitimacy toward their stakeholders.

Second, regarding variables related to H2, we find that the variables explaining the first stage of climate transparency differ from those

Table 6
Part 2 of 2P-FRM – Compliance with TCFD recommendations.

	(1)	(2)	(3)	(4)	(5)
ISO 14000	0.028***	0.028***	0.028***	0.029***	0.028***
CSR External Audit	0.046***	0.046***	0.046***	0.046***	0.048***
CO_2 Emission	0.008***	0.008***	0.008***	0.008***	0.008***
SDG 13	0.020***	0.020***	0.020***	0.020***	0.021***
Institutional Share	0.002**	0.002**	0.002**	0.002**	0.002*
Laws&Policies	0.002***	0.002***	0.002***	0.002***	0.002***
Gender Diversity	0.000	0.000	0.000	0.000	
Independent board	−0.000	−0.000	−0.000		
Env-controversies	0.010	0.010			
CSR Committee	−0.008				
Log Assets	0.006***	0.006***	0.006***	0.007***	0.006***
Tobin 5Y	−0.002	−0.002	−0.002	−0.001	−0.002
EPI	0.000	0.000	0.000	0.000	0.000
N	737	737	737	737	737
Log-lik.	−244.154	−244.158	−244.167	−244.208	−244.240
AIC	516.307	514.316	512.334	510.416	508.480
BIC	580.743	574.149	567.565	561.045	554.506

The coefficients are the marginal effects. The dependent variable is the CRORI, a continuous variable defined over a unit interval. Column (1) gives the results of the full model. Column (5) gives the results of the parsimonious model. The other columns give the results of alternative specifications.

  * significant at 10%
  ** significant at 5%
  *** significant at 1%.

explaining the second stage. In line with Peters and Romi (2014) and Fatemi et al. (2018), the results show that companies that have set up a CSR committee have a much higher probability of responding to the CDP questionnaire, as the marginal effect equals 0.199. We also find that the percentage of independent board members positively influences the first stage of climate transparency, confirming the study of Liao et al. (2015) and Kılıç and Kuzey (2019). More precisely, Fig. 1a shows that when a firm has no independent board members, the likelihood of answering the CDP questionnaire is approximately 0.55, whereas it jumps to 0.68 when the board is fully independent. In addition, we find that CSR External Audit strongly influences firms' level of compliance with the TCFD recommendations, as the predicted CRORI of firms that have implemented a CSR External Audit is 0.048 higher than the predicted CRORI of firms that have not. These findings are in line with those of Di Marco et al. (2022), who assert that purchasing assurance services for nonfinancial disclosures seems to benefit TCFD compliance. In contrast, *Gender Div.* is never significant in both parts of the model, which is not consistent with the papers of Katmon et al. (2019) and Liao et al. (2015), who find a positive relationship between the presence of women on a board and the level of CSR disclosures and GHG emissions disclosure, respectively. This may be explained, first, by the size of the sample, which is composed of the largest international firms, and, second, by the dependent variable, which focuses on climate transparency. These results only partially confirm H2, which assumes a positive relationship between governance mechanisms and climate transparency. These mixed results confirm the dual nature of the decision regarding firm climate transparency and the relevance of distinguishing its two stages.

Third, with regard to the influence of ownership structure on a firm's climate transparency, we find an opposite impact on the two stages of climate transparency. Fig. 1b shows that when the share of institutional investors increases from 0% to 40%, the probability of responding to the CDP questionnaire decreases by approximately 0.2. Conversely, Fig. 2c shows that when the share of institutional investors increases from 0% to 40%, the predicted CRORI increases by approximately 0.06. These results indicate that institutional ownership discourages disclosure, but when the company chooses to disclose, institutional ownership

encourages the company to comply with TCFD recommendations. These results are in line with those of Ntim et al. (2013) and Harjoto et al. (2015), who found a negative relationship or no relationship between institutional ownership and sustainability disclosure. This can be explained by the fact that institutional investors have distinct preferences in term of the time horizon, implying different levels of firm monitoring or influence.

Fourth, regarding the impact of environmental/climate regulations on climate disclosure, surprisingly, we find no evidence that companies that respond to the CDP are those that are in countries with the most climate regulations (*Laws&Policies*). This result is inconsistent with those of Grauel and Gotthardt (2016) and Ben-Amar and Chelli (2018), who show that firms in countries with more stringent environmental regulations are more likely to participate in CDP. This difference can certainly be explained by the relatively older study periods (2011 to 2015) when few companies were responding to the CDP questionnaire.[13] However, we find that *Laws & Policies* positively influence the second stage of climate transparency. As illustrated in Fig. 2d, when the number of laws and policies in a country is close to 0, the predicted CRORI is approximately 0.75, whereas when this number is high (approximately 55), the predicted CRORI is approximately 0.85. These results are in line with those of David and Giordano-Spring (2022), who show that the level of compliance with the TCFD seems to be influenced by the regulatory measures of the home country. That is, the degree of legal enforcement influences the extent to which firms comply with the TCFD recommendations and is consistent with H4, according to which there is a positive relation between environmental/climate regulations and climate disclosure.

Finally, regarding the control variables, we find that large and financially performing firms originating from countries displaying a high *CC EPI* are more likely to respond to the CDP questionnaire. Fig. 1c shows that the predicted probability of responding to the CDP questionnaire jumps from <0.4 when the firm is small to almost 0.9 when the firm is large. Similarly, Fig. 1d shows that the predicted probability of responding to the CDP questionnaire is almost 0.20 higher when the firm is a high financially performing firm compared to a low performing firm. Regarding the *CC EPI*, we find that the predicted probability of responding to the CDP questionnaire is approximately 0.15 when the *CC EPI* equals 0.15 and reaches >0.8 when the *CC EPI* equals 0.95. For the second stage of transparency, we find that the predicted CRORI increases from 0.79 for small firms to 0.85 for large firms, confirming the relevance of firm size for explaining climate transparency. In contrast, we find that firms' financial performance and the *CC EPI* of the home country have no influence on the second stage of climate transparency.

4.2. Some refinements on the climate transparency analysis
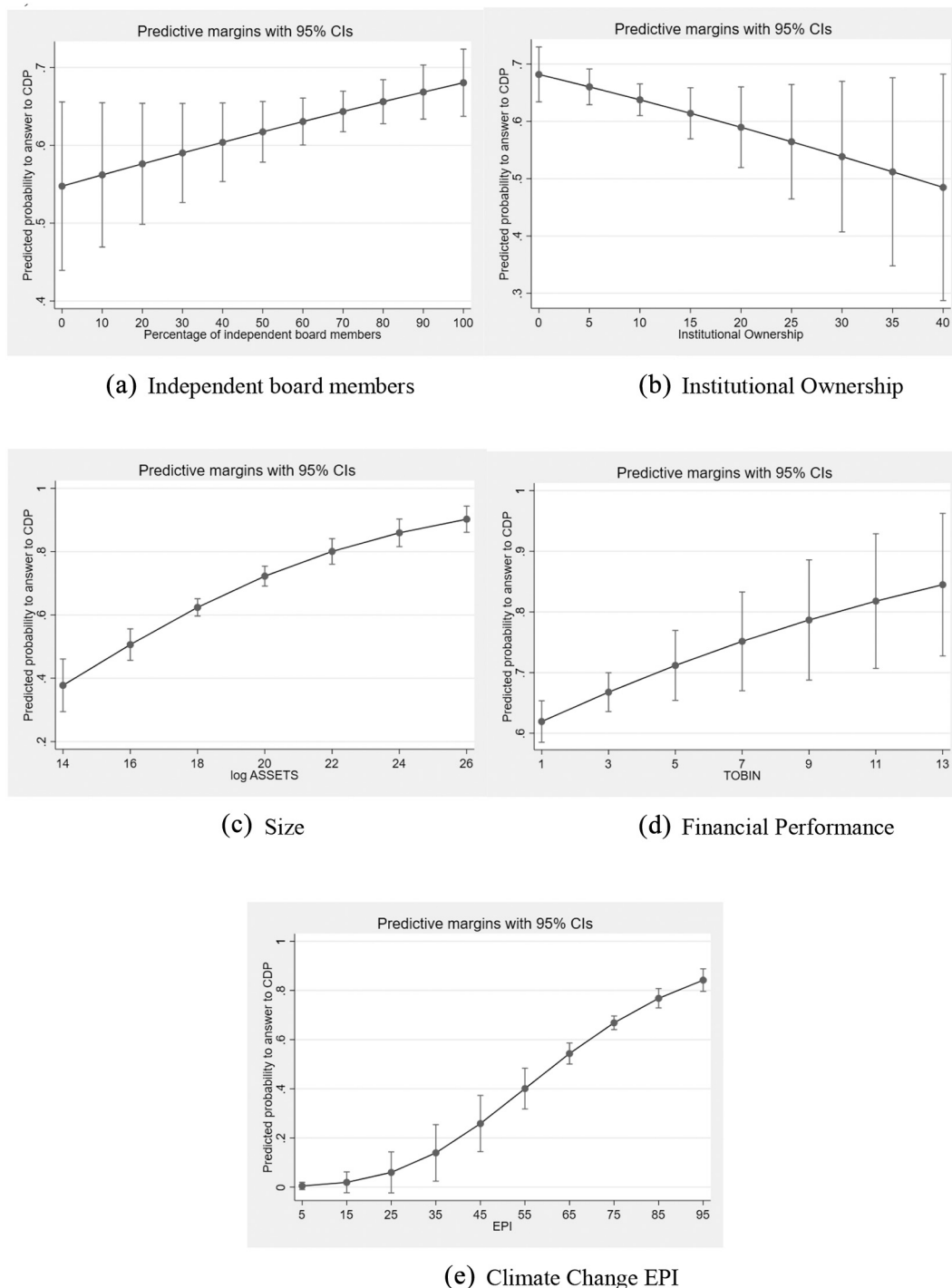
4.2.1. Drivers by sectors

The analysis is refined by differentiating the drivers of climate transparency considering firms operating in industries facing high (resp. low) environmental stakes. High-stakes include the following sectors: finance, energy, transport, food and materials and buildings; and low-stakes include all other sectors. Table 7 displays the results of the 2P-FRM for these two subsamples.

These results highlight that the determinants of climate transparency are not the same across firms that belong to sectors with low and high environmental stakes.

Regarding the response to the CDP questionnaire (binary part of the 2P-FRM), we find that among the variables that were significant in the general model, *CSR Committee* is significant for high and low-stakes industries (with similar marginal effects). Regarding the level of

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[13] This is evidenced by the number of respondents to the CDP questionnaire of 6037 in 2011, 10,815 in 2015 and 21,884 in 2021 (www.cdp.net, section "Search and view past CDP responses").

(a) Independent board members

(b) Institutional Ownership

(c) Size

(d) Financial Performance

(e) Climate Change EPI

Fig. 1. Predicted changes in the probability of responding to the CDP questionnaire.
Fig. 1a (1b, 1c, 1d and 1e) presents the predicted probability of answering the CDP questionnaire depending on *Indpdt. Board* (resp. *Instit. Own.*, *log Assets*, *5Y Tobin* and CC *EPI*). These estimates are based on Model 6 (see Table 5).
Fig. 1a Independent board members.
Fig. 1b Institutional Ownership.
Fig. 1c Size.
Fig. 1d Financial Performance.
Fig. 1e Climate Change EPI.

compliance with the TCFD recommendations (fractional part of the 2P-FRM), we find that among the variables that were significant in the general model, only *SDG 13, CSR Ext. Audit* and *Laws&Policies* are significant for both high and low-stakes industries (with a significant magnitude).

Regarding firms operating specifically in high-stakes industries, we find that firms that are the most likely to respond to the CDP questionnaire are those that faced environmental controversies, have a large proportion of independent board members, and originate from countries that have issued many climate regulations. In addition, firms operating
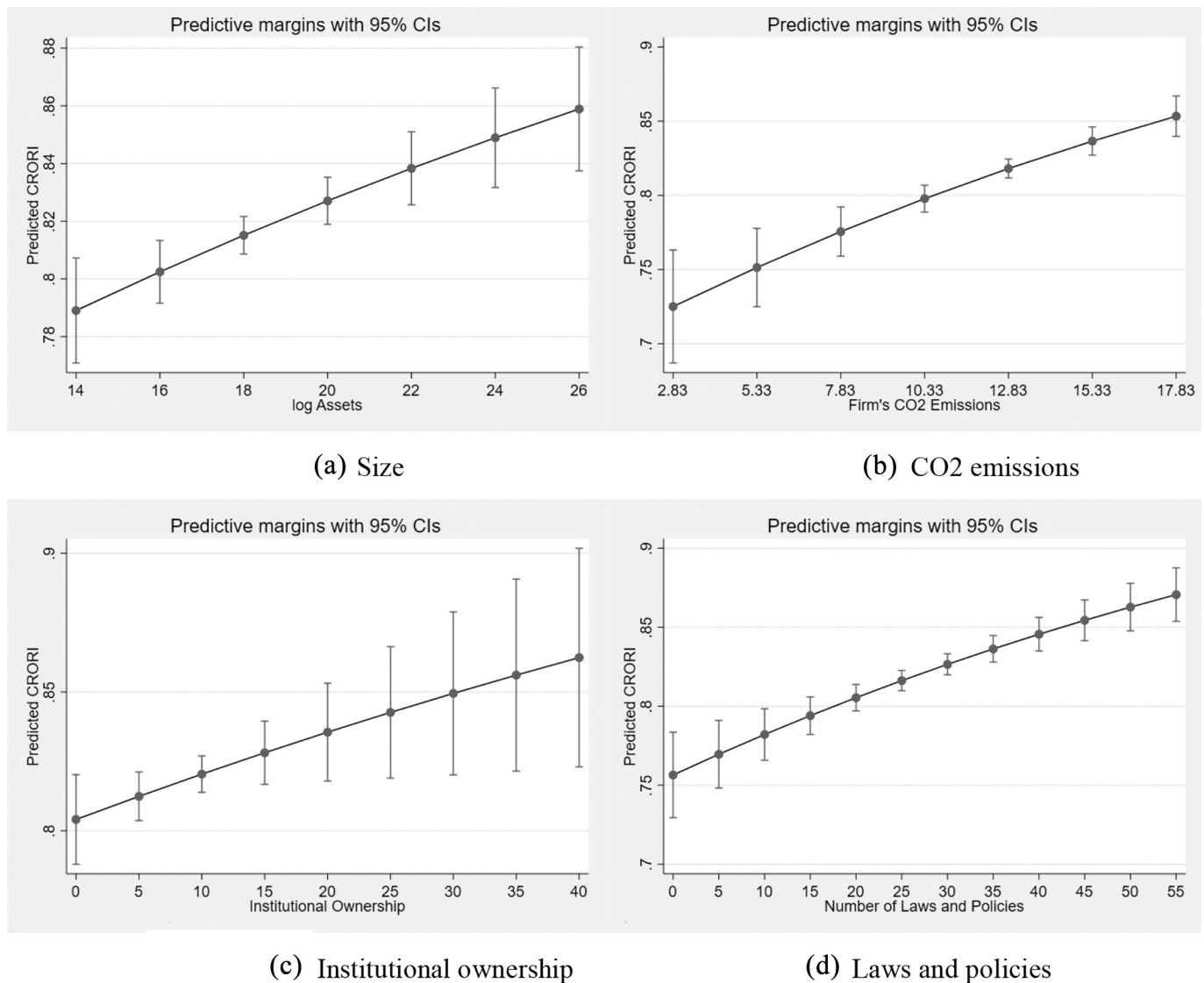
(a) Size

(b) CO2 emissions

(c) Institutional ownership

(d) Laws and policies

Fig. 2. Predicted changes in the CRORI.

Fig. 2a (2b, 2c, 2d and 2e) presents the predicted CRORI depending on *log assets* (resp. *CO₂ Emissions*, *Instit. Own.* and *Laws&Policies*). These estimates are based on Model 6 (see Table 6).

Fig. 2a Size.

Fig. 2b CO₂ emissions.

Fig. 2c Institutional ownership.

Fig. 2d Laws and policies.

in high-stakes industries tend to display a higher CRORI if they have high *CO₂ emissions* and a large share of institutional investors.

4.2.2. Drivers by region

The analysis is also refined by differentiating the determinants of climate transparency considering three geographic areas: Anglo-Saxon countries, Europe and Asia. Table 8 displays the results of the 2P-FRM for these subsamples.

This new analysis is informative in several ways. First, we find that the drivers of climate transparency differ widely across regions. Indeed, no variable is significant and with the same sign for the three geographical areas considered. Second, some variables that were significant in the general model turn out to be irrelevant when focusing on specific regions. In particular, European companies stand out in this respect as follows: i) *ISO 14000* is no longer significant for explaining both stages of climate transparency; ii) *CSR Committee* and *Instit. Own* do not influence the probability of responding to the CDP questionnaire;

and iii) it is the only geographic area where the higher the CO₂ emissions, the higher the CRORI. Asian companies also exhibit some peculiarities, as their probability of responding to CDP is not influenced by *Env. Controv.* and their CRORI is not affected by *CSR Ext. Audit* (two variables that were significant in the general model). Finally, some variables that were not significant in the general model have significant explanatory power depending on the subsample considered. Interestingly, we find that in Anglo-Saxon and Asian countries, the more polluting the company is, the more likely they are to answer the CDP questionnaire, whereas the opposite is true for European companies, confirming the duality of legitimacy theory. Overall, these results reveal strong heterogeneity between geographic areas regarding climate transparency. This reveals the need for incentive mechanisms, regulations or organizational arrangements adapted to regional specificities.

Table 7

Part 1 and Part 2 of the two-part fractional regression model (2P-FRM) – Industries with low/high environmental stakes.

	Binary Part		Fractional Part	
	CDP-Low-stakes	CDP-High-stakes	CRORI Low-stakes	CRORI High-stakes
ISO 14000	0.193***		0.038***	
SDG 13			0.020*	0.027***
Envi-Controversies		−0.250***		
CO$_2$ Emissions				0.011***
CSR Committee	0.202**	0.209***		
CSR Ext. Audit	0.157***		0.053***	0.055**
Indpdt. Board		0.002**		−0.000**
Instit. Own.				0.002**
Laws&Policies		0.005**	0.003***	0.002***
Assets		0.065***	0.012***	
Tobin 5Y		0.52**		
EPI		0.015***		
N	514	628	338	399
Log-lik.	−312.630	−358.096	−114.837	−128.982

This table presents the results of the 2P-FRM on two subsamples: firms operating in industries with low (resp. high) environmental stakes. The first two columns give the results of the first part of the 2P-FRM, which is the binary decision to disclose information. The last three columns give the results of the second part of the 2P-FRM, that is, the fractional decisions on the level of disclosure of standardized information on CROs. The coefficients are the marginal effects. Each column gives the results of the parsimonious models.

* significant at 10%
** significant at 5%
*** significant at 1%.

4.3. Robustness analysis

4.3.1. Relevance of the two-part model

To test the appropriateness of the two-part specification of the fractional regression model, we rely on the P-test statistic proposed by Davidson and MacKinnon (1981), which allows us to compare nonlinear models. One of the advantages of the P-test lies in the fact that it may be applied to the full specification of the two-part model to thus compare the relevance of the two-part model (based on logit, probit, loglog and cloglog) with the one-part model (based on logit, probit, loglog and cloglog). The results of these specification tests are presented in Table 9. The 16 bilateral tests all reject the 1P-FRM and select the 2P-FRM. This clearly supports the assumption underlying the choice of the 2P-FRM, namely, that transparency is a process that involves different stages,

Table 9

Specification tests.*, **

	2-part logit	2-part probit	2-part loglog	2-part cloglog
1-part logit vs.	38.106***	37.477***	42.529***	33.871***
1-part probit vs.	38.052***	37.407***	42.482***	33.785***
1-part loglog vs.	36.293***	35.839***	39.751***	33.144***
1-part cloglog vs.	40.357***	39.552***	45.440***	35.126***

This table presents the p-values of P-tests. Columns (1)–(4) correspond to valid models under the alternative hypothesis. Rejection of the null hypothesis is to be interpreted as rejection of the model under the null hypothesis (row model) in favor of the alternative model (column model). The models are estimated with the benchmark set of explanatory variables.

* significant at 10%
** significant at 5%
*** significant at 1%.

such as a continuum, depending on the nature and characteristics of the corresponding disclosures.

4.3.2. Subsample sensitivity analysis

We check the robustness of the results to confirm that the estimated coefficients are not dependent on particular model specifications and data points. Table 10 and Table 11 present the results of the binary and fractional parts of the 2P-FRM for different subsamples, respectively. We first separately consider 2020 and 2021 (columns (2) and (3), respectively) to check that the results of the baseline models are not driven by year-specific effects. In addition, we estimate the baseline models without the top and bottom 1% and 5% CRORI data to check that the results are not determined by a small number of observations. The estimates are robust across the different datasets.

5. Discussion and conclusion

In recent years, the strengthening of climate disclosure regulations has been underway in many countries. This regulatory tool is the path favored by regulators to address climate change to improve climate transparency and to then make corporations' investments change to low-carbon investments. However, a distinction between transparency and disclosure is useful: the former is the ultimate aim, while the latter is the means to achieve it. It follows that the nature and reliability of these disclosures and their effectiveness related to the change in corporations' investments to low-carbon projects are a key issue in discussions with regulators. From this perspective, it is necessary to better understand

Table 8

Part 1 and Part 2 of the 2P-FRM – Geographic areas.

	Binary Part			Fractional Part		
	Anglo-Saxon Countries	Europe	Asia	*Anglo-Saxon Countries*	Europe	Asia
ISO 14000	0.119***		0.237***	0.024**		0.122***
SDG 13	0.032***					
Env-Controversies	−0.290***	−0.270**		0.060***		
CO$_2$ Emissions	−0.020**	0.024**	−0.060***		0.017***	
CSR Committee	0.169*		0.219*			−0.0511**
CSR Ext. Audit				0.039***	0.082***	
Indpdt. Board					−0.000*	
Gender Div.			−0.008**		0.002***	
Instit. Own.	−0.019***		−0.007*			
Assets	0.076***	0.025*				
Tobin 5Y	0.036**		−0.118***	−0.009***		
N	532	384	180	330	255	144
Log-lik.	−320,625	−239,140	−73,552	−118,132	−81,780	−40,542

The first three columns give the results of the first part of the 2P-FRM, which is the binary decision to respond to the CDP questionnaire. The three last columns give the results of the second part of the 2P-FRM, that is, the fractional decisions on the level on the level of compliance with TCFD (CRORI). The coefficients are the marginal effects. Each column gives the results of the parsimonious models.

* significant at 10%
** significant at 5%
*** significant at 1%.

Table 10
Robustness test – subsample analysis – binary part of the 2P-FRM.

	Baseline model	2020	2021	Bottom 1% of CRORI dropped	Bottom 5% of CRORI dropped	Top 5% of CRORI dropped	Top 1% of CRORI dropped
Constant	−7.343***	−6.913***	−7.708***	−7.336***	−7.493***	−7.452***	−7.307***
ISO 14000	0.339***	0.308**	0.368**	0.351***	0.379***	0.309***	0.343***
CSR Committee	0.764***	0.747***	0.748**	0.752***	0.755***	0.714***	0.761***
Env-controversies	−0.965***	−1.088***	−0.962***	−0.953***	−0.947***	−0.996***	−0.960***
Independ. Board	0.005*	0.004	0.006	0.005**	0.005**	0.006**	0.005*
Institutional Share	−0.017*	−0.015	−0.021	−0.017*	−0.016	−0.018*	−0.017*
logASSETS	0.204***	0.175***	0.235***	0.201***	0.206***	0.206***	0.202***
TOBIN	0.093**	0.080	0.099*	0.090**	0.084**	0.101**	0.092**
EPI	0.044***	0.045***	0.043***	0.044***	0.044***	0.044***	0.044***

This table presents the results of the binary part of the 2P-FRM for different subsamples. Column (1) presents the results of the baseline model (see model (6), Table 5). Column (2) (resp. (3)) presents the results when considering only 2020 (resp. 2021). Columns (3)–(6) present the results when extreme CRORI observations are dropped from the analysis.

 * significant at 10%
 ** significant at 5%
 *** significant at 1%.

Table 11
Robustness test – subsample analysis – fractional part of the 2P-FRM.

	Baseline model	2020	2021	Bottom 1% of CRORI dropped	Bottom 5% of CRORI dropped	Top 5% of CRORI dropped	Top 1% of CRORI dropped
Constant	−0.683**	−0.717	−0.645	−0.722**	−0.388	−0.591**	−0.604*
ISO 14000	0.170***	0.163**	0.191***	0.144***	0.133***	0.163***	0.178***
CSR External Audit	0.293***	0.319***	0.216**	0.279***	0.284***	0.276***	0.309***
CO_2 Emission	0.047***	0.052***	0.044***	0.050***	0.051***	0.043***	0.046***
SDG 13	0.126***	0.079	0.080	0.148***	0.107***	0.152***	0.126***
Institutional Share	0.010*	0.013*	0.006	0.008*	0.006	0.011**	0.011**
Laws&Policies	0.013***	0.012***	0.013***	0.014***	0.011***	0.011***	0.012***
logASSETS	0.037***	0.033**	0.042***	0.043***	0.030***	0.033***	0.034***
TOBIN	−0.010	−0.021	−0.007	−0.007	−0.012	−0.011	−0.011
EPI	0.002	0.002	0.003	0.001	0.002	0.002	0.001
Log-lik.	−244.240	−119.457	−124.443	−238.368	−221.782	−234.709	−243.388
N	737	348	389	729	699	693	733

This table presents the results of the fractional part of the 2P-FRM for different subsamples. Column (1) presents the results of the baseline model (see model (6), Table 6). Column (2) (resp. (3)) presents the results when considering only 2020 (resp. 2021). Columns (3)–(6) present the results when extreme CRORI observations are dropped from the analysis.

 * significant at 10%
 ** significant at 5%
 *** significant at 1%.

firms' climate transparency and the levers that can improve it. This paper aims to identify the key drivers of firms' climate transparency. Using a two-part fractional response model, we consider transparency to be a process that involves different stages, depending on the nature and characteristics of the disclosures. In particular, we investigate two levels of transparency: the first comprises firms' likelihood of responding to the CDP survey, and the second consists of their level of compliance with TCFD recommendations.

The estimation results shed some light on the potential impact of corporates' environmental performance, governance mechanisms and regulatory frameworks on transparency regarding CROs. First, we document that different drivers explain the two stages of transparency. This finding may be related to the two concepts of transparency described by Brunnschweiler et al. (2021): i) narrow transparency, which is restricted to information disclosure, and ii) the broadest transparency, which refers to the ability of targeted actors to assimilate, process and utilize the information disclosed. The main difference between these two definitions lies in the dissemination of the disclosures to influence the behavior of targeted actors (Mitchell, 2011). The first stage of climate transparency, responding to the CDP questionnaire, may be seen as a proxy for narrow transparency, whereas the second stage of transparency, the level of compliance with TCFD recommendations, is a proxy for a broader conception of transparency. Indeed, if the CDP questionnaire offers effective information, it has become a data provider, which means that the disclosure does not necessarily reach the

target. On the contrary, in the TCFD final report, all the recommended disclosures are supposed to be included in firms' financial filings to provide decision-useful information. The reason is that information sharing lies in the center of the TCFD framework (Chenet et al., 2021).

Regarding the first stage of climate transparency, the results show that firms that are the most likely to respond to the CDP questionnaire are large, are financially performing, do not suffer from negative media exposure regarding their climate commitment and display board diversity (independent members and a CSR committee). Regarding firms' compliance with the TCFD recommendations, we find that firms that display a higher CRORI are large companies that have high carbon emissions, they have set up an EMS and a CSR external audit (except for the Asia zone), and that are located in countries that have issued a large number of climate laws and policies. The contrasted impact of climate performance on the two stages of transparency highlights the duality of firms' legitimization practices and explains the mixed results in the empirical literature regarding the link between climate performance and voluntary disclosure (Ding et al., 2023). While virtuous companies disclose to promote their actions to stakeholders, the most polluting companies disclose to increase their legitimacy and avoid market sanctions (Braasch and Velte, 2023). In addition, these results highlight the complementarity of governance mechanisms for climate transparency and the importance of combining several mechanisms. Indeed, the establishment of mechanisms allows companies to improve their climate reporting, which reduces information asymmetry and allows

financial markets to function more efficiently and to foster low-carbon investments.

Interestingly, we find that the only factor that positively influences both levels of climate transparency is the establishment of a third-party certified EMS such as ISO 14000 certification. This impact is even more important in Anglo-Saxon and Asian countries. This result may be explained by the fact that ISO 14000 falls into the category of voluntary standards that can be considered cost-effective alternatives to regulation (McGuire, 2014). Indeed, firms voluntarily over-comply with regulations to gain competitive advantages, improve their performance (Wang et al., 2023) or capitalize on the "green" price premiums offered by environmentally conscious consumers (Eriksson, 2004). As underlined by Coglianese (2020), such a soft legal governance system offers advantages that makes it appealing, as it seems more politically feasible to establish and easier to adapt in the face of changing circumstances. Voluntary environmental governance systems that aim to increase climate transparency should require documented and consistent disclosures (Coglianese, 2020).

When refining the analysis by subsample, the results highlight that the drivers of climate transparency differ by geographic area or sector, indicating that these specificities should be considered to provide effective incentives to improve corporate climate transparency. One possible explanation for this regional heterogeneity is cultural differences. As documented in the literature, cultural factors largely influence corporate strategy, managerial practices, and environmental disclosures (Gallego-Alvarez et al., 2017; Pucheta-Martínez and Gallego-Álvarez, 2020). The sectoral heterogeneity may be explained, first, by the necessity for companies that are heavily exposed to the effects of climate change to adapt their strategies, as they are already experiencing losses in value due to extreme weather events, disrupted operations, and environmental regulations. In addition, it can arise from a need to gain legitimacy with stakeholders (Marco-Fondevila and Álvarez-Etxeberría, 2023). Indeed as underlined by Braasch and Velte (2023) carbon-sensitive firms are more likely to engage in symbolic climate reporting practices.

The climate regulatory framework is a significant determinant regarding the second level of transparency, which is the type of disclosure that may make it possible to improve information quality and move toward greater accountability. Regulators are aware of this issue, which is why, some initiatives underway at the international level (ISSB[14]) go in this direction. The purpose is to create a sustainable standard (IFRS Sustainability) related to climate that provides investors and other capital market participants with information about companies' sustainability-related risks and opportunities to help them make informed decisions. This implies making climate disclosures mandatory. Notably, the exposure draft on IFRS S2 climate-related disclosures is more or less based on TCFD recommendations; thus, the CRORI can become a measure of the compliance with IFRS S2.

While our results are of interest to managers and regulators, they should be evaluated in light of several methodological shortcomings. The first limitation relates to data availability: i) S&P 1200 firms that do not disclose their GHG emissions are not included in the sample; ii) the analysis covers only large capitalizations; and iii) the 2020–2021 period does not allow us to analyze the potential learning effects regarding corporate transparency practices related to CROs. Second, the firms in the sample were observed only cross-sectionally. Although the subsample analysis allows us to consider regional and sectoral heterogeneity and the robustness analysis shows that the results are not driven by year effects, there may be important firm-level heterogeneity that can be addressed only by using panel data.

In addition, further research opportunities arise from this analysis. First, while climate regulations and policies are helping to improve the quality of corporate climate disclosures, the fact remains that disclosure is a prerequisite for the effectiveness of climate transparency as a necessary but not sufficient condition to reallocate investments and to encourage companies to reduce their GHG emissions. As underlined by Ameli et al. (2020) and Chenet et al. (2021), while transparency can help, on its own, it is a very long way from an adequate response to the challenges of "aligning institutional climate finance". Effectiveness can only be assessed in terms of how well corporations reduce the asymmetries in CROs and make informed decisions to redirect investments toward low-carbon projects. It would also be interesting to investigate to what extent climate transparency actually redirects investments. Second, while the financial crisis of 2007–2008 highlighted the failure of self-regulation to prevent the failure of financial institutions and systemic risk, it is interesting to see that regulators have also chosen this form of intervention: disclosures regulation. Considered less restrictive and, therefore, more acceptable to economic agents, this form of regulation encourages rather than forces companies to disclose their exposure to the fossil fuel sector. For this reason, some authors raise the question of the effectiveness of transparency-based financial policies to face climate change challenges and underline the undervaluation of climate-related information as a relevant source of information by investors (Hook and Vincent, 2020). It would be interesting to investigate potential alternative or complementary policies, such as Chenet et al. (2021), who propose a framework that draws on both the "precautionary principle" and modern macroprudential policy.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Data availability

The data that has been used is confidential.

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[14] The International Sustainability Standards Board (ISSB) is a standard-setting body established in 2021–2022 as part of the IFRS Foundation with a mandate to create and develop sustainability-related financial reporting standards to meet the environmental reporting needs of investors.

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