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ORIGINAL ARTICLE

Disclosure of climate risk information by the world's largest companies

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Abstract The risks related to global climate change are seen as threats to companies, taking into consideration their impact on the return on investment. In order to mitigate climate risk and introduce new opportunities to financiers, companies need to identify, manage, and report climate risks. The purpose of this paper is to investigate the climate risks disclosed by the 100 largest companies in the world, according to the Bloomberg and Price Waterhouse Coopers

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(PwC 2015) classification, and identify some characteristics of these companies that explain the disclosure level of such information. Preliminary results revealed that of the companies investigated, 14% did not disclose any climate risk information in the Carbon Disclosure Program (CDP) report. Also, from the companies that disclosed information according to the Global Reporting Initiative (GRI), 9.9% did not provide information regarding policies, actions, and strategies for mitigating the risks related to climate change. The results shown by the content analysis suggested that, in general, there is still a low level of disclosure about climate risks by these companies. The final results through econometric instruments and statistical tests indicate that the size of the company or the fact that corporations are from developed countries do not necessarily explain the level of information disclosed. However, the activity sector, the continent, and the efficiency of the Board of Directors are factors that strongly explain the level of climate risk disclosure. We conclude that more effort is needed to encourage an engaging attitude from corporations to develop actions, policies, and strategies to mitigate climate change risks and threats. In addition, the world's largest companies should make a greater investment in climate risk disclosure.

Keywords Climate risk disclosure · Global Top 100 · Climate changes · Theory of legitimacy · Strategies for climate change · Adaptation and mitigation

1 Introduction

Global climate change represents an urgent threat and is causing a potentially irreversible impact on humanity and the planet. There will be significant negative environmental, social, and financial impacts on a global scale, if an appropriate strategy to confront these issues is not implemented in the very near future (IPCC, 2001, 2007, 2014). Additionally, climate change can affect a firms' profitability. Thus, investors can ask questions about how these issues are being addressed and what business opportunities are arising from these changes. For example, how are the increased costs arising from carbon dioxide emissions and associated climate risks being controlled or managed?

One approach organizations use to meet stakeholder's demands is the voluntary disclosure of information. Communication is a crucial element of the legitimation process, because even if corporate activities reflect social values, legitimacy may be threatened when communication failure happens. The social responsibility of the disclosure process can be understood as a provision of information related to the interaction of an organization with its physical and social environment. In international literature, environmental disclosure has been widely studied (Rodrigue et al. 2013; Suttipun and Stanton 2012a; Cho et al. 2012; Clarkson et al. 2008; Cho and Patten 2007; Aerts et al. 2004; Cormier and Magnan 1997; Nazli and Sulaiman 2004; Patten and Trompeter 2003; Byard and Shaw 2003; Baginski et al. 2002; Stanwick and Stanwick 2000; Williams 1999a; Hackston and Milne 1996; Entwistle 1999; Frankel et al. 1995; Fried 1984; McNichols and Manegold 1983; Lang and Lundholm 1993; Cooke and Wallace 1990; Zeghal and Ahmed 1990; Leftwich, et al. 1981).

During the last decade, there has been an emergence of a new research trend focusing on the disclosure of climate change information rather than on the environment. This may be due to a worldwide concern about global climate change issues. As a result, while some studies have investigated corporate disclosure of climate change information (Amran, et al. 2014;

Cotter and Najah 2012; Pellegrino and Lodhia 2012; Dawkins and Fraas 2011; Reid and Toffel 2009, Stanny and Ely 2008; Smith et al. 2008; Mills 2007), other works have been developed with a specific focus on investigating climate change strategies for cities, regions, and countries around the globe (Lee and Hughes 2017; Li and Jia 2017; Rohat et al. 2017; Halsnæs et al. 2014; Bierbaum et al. 2013).

Meanwhile, in recent literature, attention has turned towards a group of researchers specifically focused on corporate climatic risk information disclosure (Da Silva Gomes et al. 2017; Kouloukoui 2016; Leurig and Dlugolecki 2013; Leurig 2011; Broder 2010; Corporate Library Inc. 2009; Doran et al. 2009; Doran and Quinn 2009; Fordham and Corp. and Fin. L. 281, 2008. This study fits in the latter group as it seeks to investigate the disclosure of climate risk information.

The non-disclosure of information about risks related to climate change and performance has consequences for businesses as a judgmental market can draw conclusions based on incomplete information. In addition, such information disclosure reduces the age-old problem of information asymmetry between the principal and the agent. Therefore, the question follows: what kind of information is being disclosed when it comes to climate risks, and which specific characteristics of a company can explain and influence the amount of disclosure information about climate risks?

As shown in previous research, many organizations are facing challenges and pressure to demonstrate their strategies and practices when facing climate change—for example, Wittneben and Kiyar (2009), Pinkse and Kolk (2009), and Ziegler and Hoffmann (2011). Other research has addressed the relationship between business responses to climate change and a company's economic and financial performance (Ziegler et al. 2011; Boiral et al. 2012; Lee 2012; Kennedy et al. 2014; Chakrabarty and Wang 2013; Böttcher and Müller 2015; Hallenberg 2015; Lee et al. 2015). Most researchers found a positive relationship between these two variables. Haque et al. (2013) investigated the perceived difference between expected information by stakeholders and the information released by Australian corporations. Haque and Deegan (2010) also examined the disclosure practices of corporate governance related to climate change by five major Australian companies over a 16-year period.

Pauw et al. (2016) analyzed 101 case studies of private sector adaptation under the Private Sector Initiative (PSI) of the United Nations Framework Convention on Climate Change (UNFCCC) Nairobi work program. They compared the case studies against ten "adaptation finance criteria" that were extracted from the UN climate negotiation outcomes. De Aguiar and Bebbington (2014) analyzed the nature of information disclosure regarding climate change in annual reports, not considering the emission trading organizations participation in the United Kingdom. On the other hand, Nikolaou et al. 2015investigated the evolution of relationship trends between climate change and climatic risks, financial performance, and the operational processes of companies. Linnerooth-Bayer and Hochrainer-Stigler (2015) suggested a risk management approach to reduce the threat and spread into different layers of risk, including a layer that represents a possible adaptation deadline. However, what do the world's 100 largest companies disclose in their sustainability reports on climate risk management practices?

This paper firstly aims to investigate the climate risks disclosed by the 100 largest companies in the world, according to the Bloomberg and Price Waterhouse Coopers (PwC 2015) classification, and secondly to identify which characteristics of a company can explain the disclosure level of such information. In this paper, the use of the expression "climate risk

disclosure" refers to corporate reports about policies and proactive procedures that organizations have in place to deal with risks related to climate change.

Studies on climate risk disclosure are scarce. At this point, it is worth mentioning that information disclosed on climate change is not mutually exclusive to that disclosed on climate risks. Climate change information encompasses all data and is therefore more generic. On the other hand, climate risk data is more specific, referring to a set of information about threats linked to climate change and the strategies developed by companies to mitigate them. Therefore, this study aims to contribute to literature and focuses on the 100 largest companies in the world. Such a study has not yet been developed. This study also provides some useful contributions from existing literature regarding discussions about climate risk reports. The world's largest companies, as they have more resources than smaller ones, are therefore expected to act first towards climate change threat mitigation and adaptation. In order to broaden knowledge, this research investigates the information disclosed by these companies, using statistic models to investigate empirically which characteristics of a company can explain the level of disclosure about climate risks.

2 Literature review and hypothesis

According to Pellegrino and Lodhia (2012), the theory of legitimacy has been used to explain the voluntary disclosure of environmental information by several researchers (for example Dowling and Pfeffer 1975; Patten 1991, 1992; Lindblom 1994; Deegan and Rankin 1996; Lodhia 2005; Deegan 2007). The theory is derived from organizational legitimacy, which has been defined as a condition or situation that exists when the value system of a corporation is congruent with the value system of the society of which the entity is a part of O'Donovan 2002a).

According to this theory, companies act in a society and therefore a sort of social contract is formed between the organizations and the society in which they operate, representing a set of implicit and explicit expectations of its members as to how they should act (Deegan, 2006, 2007; Gray et al. 1995). These authors suggest that legal requirements provide the explicit contract terms, while requirements that are not legally binding provide the expectations of society and incorporate implicit contract terms. Legitimacy is a general perception that entity actions are desirable or appropriate within a socially constructed system of norms, values, beliefs, and definitions (Suchman 1995).

Therefore, an organization's survival might be threatened if society perceives that it is not acting at an acceptable or legitimate level to continue with its operations. Thus, the implicit premise is that society, as a set of individuals, allows an organization to continue to operate as long as the organization considers the rights of the general public, in accordance with society's expectations (Deegan 2006, 2007). So, it is understood that there is a reaction from the organization's managers regarding social concerns and expectation changes. As a result, organizations must adapt and change, or at least try to be perceived as functioning within the ever-changing limits of their respective societies' standards, in order to guarantee their right to exist (Deegan 2006, 2007; O'Donovan 2002b).

Consequently, in order to manage organizational legitimacy, companies must know how they can acquire, maintain, or lose legitimacy. Because of negatively perceived consequences,

an extreme situation or scenario could be a threat to survival; a company may evaluate its legitimacy status and communicate this status to the relevant stakeholders or engage in legitimization efforts (Lindblom 1994). To do this, a company has two attitudes to control legitimacy: actions and presentation. While the first refers to the activities developed by the company in congruence with social values, the second refers to the disclosure of corporate activities in line with social values. Consequently, communication is a crucial legitimacy process element, because even if corporate activities adhere to social values, legitimacy may be threatened because of communication failures. The corporate social disclosure process may be understood as one that provides financial and non-financial information regarding the organization's interaction with its physical and social environment, disclosed both in yearly reports and in specific reports.

Previous studies have also suggested that events or issues are fundamental key catalysts of an organizational legitimacy threat, causing organizations to become involved in legitimate discursive strategies (Nasi et al. 1997; Patten 1992; O'Donovan 1999a, b). Finally, there is research which examines the theory of legitimacy applied to environmental disclosure (Deegan and Rankin 1996; Brown and Deegan 1998; O'Donovan 2002a, b; Deegan et al. 2007). However, very little is known about risk practice disclosure and opportunities related to climate change and characteristics of the company that explain the disclosure level of such information. This is the main focus of this study.

Large companies should respond with more disclosure because they have a greater impact on social expectations, considering that they have more stakeholders than small companies (Cowen et al. 1987). Several studies have demonstrated the positive relationship between environmental disclosure and company size (Deegan and Gordon 1996; Hackston and Milne 1996; Brammer and Pavelin 2006; Suttipun and Stanton 2012a). Therefore, this paper aims to test the following hypothesis:

> H1: There is a positive relationship between a firm's size and the level of climate risk disclosure.

For businesses, the context of risks related to climate change is a threat, mainly due to the impacts this phenomenon may cause on the return on their investment, organizational performance, or even in the aggregated value for investors (Labatt and White 2007). Evidence suggests that there is a growing demand from investors for information about the impact of climate change on business organizations (Global Investor Coalition on Climate Change (GICCC 2013). The study developed by Pfeifer and Sullivan (2008) examined the evolution of UK institutional investors' interest in climate change from 1990 to 2005, while focusing on policy measures and their relative contributions, such as the disclosure of information, awareness, and market-based instruments. They concluded that, over that period, flexible policy measures played an important role while encouraging investors to discuss climate change issues with companies. However, it had little impact on investment decisions. It was only with the introduction of harsh policy measures that climate change became systematically considered in investment analysis.

Previous research split companies into two types: high or low-profile firms (Suttipun and Stanton 2012b; Hackston and Milne 1996; Patten 1992). High-profile companies are the ones operating in extremely polluting industrial settings (Perry and Tse Sheng 1999; Stray and Ballantine 2000; Jennifer and Taylor 2007). These high-profile companies are therefore more exposed to the political and social environment than low-profile ones (Newson and Deegan 2002). Studies have demonstrated a relationship between the activity

sector and disclosure level (Hackston and Milne 1996; Williams 1999b). Therefore, we tested the following hypothesis:

H2: There is a relationship between the disclosure level regarding climate risks and the activity sector of the company.

Sampled companies may be split into two types: companies from developed countries and companies from emerging countries. Previous studies suggest that companies from developed countries have a higher amount of social and environmental information disclosure than those from developing countries (Adams et al. 1998; Kolk et al. 2001). The third and fourth hypotheses are presented below:

H3: Companies from developed countries have a higher level of climate risk disclosure than companies from emerging countries.
H4: There is a significant relationship between the company's location and the level of disclosure regarding climate risk.

In Jensen's (1993) view, an efficient Administrative Council should be small and, preferably, made up of external managers, with the Chief Executive Officer—CEO—as the only internal member. Agency theory argues that Administrative Councils with many members are inefficient, due to communication and coordination problems (Jensen and Meckling 1976; Fama 1980; Fama and Jensen 1983; Jensen 1993). There is also a greater chance of conflict inside the group because of the difficulty of reaching a consensus or agreement. Therefore, the size of the Administrative Council of a company is an essential aspect to its efficiency (Lipton and Balatonalmadi 1992; Jensen 1993). The research conducted by Amran et al. (2014) predicted that there is a negative relationship between the disclosure of information on climate change and the size of the Board of Directors, but the results demonstrated the opposite. Given this, the fifth hypothesis of the present study is:

H5: There is a significant negative relationship between the size of the Board of Directors and the level of disclosure of climate risk.

Studies demonstrate the importance of women participating on a corporation's Board of Directors (Carter et al. 2003; Amran et al. 2014). Evidence shows that the greater participation from women on the Board of Directors, the greater the organization's involvement and commitment to issues of climate change—the female gender is generally more sensitive to any global, social, and environmental issues. The diversity of gender on the Board leads to decisions aligned with global warming questions (Amran et al. 2014). From this, the sixth hypothesis of the research is:

H6: There is a statistically significant and positive relationship between the percentage of women on the board and the disclosure of information regarding climate risks.

It is important to remember that other variables that influence the level of corporate disclosure can be found—for example, the level of financial performance, level of indebtedness, and others. However, some of these variables were not tested given the sample's characteristics and the research questions. It makes little sense to test the level of financial performance, because the sample used is made up of the world's most

profitable companies, so it is understood that in general they all have enough resources to invest in climate risk management.

3 Method

3.1 Database population and sample

The main objective of this paper is to investigate the climate risks disclosed of the 100 largest companies in the world and then check the characteristics of the company that influence the disclosure level. To achieve this, research was carried out using the *Global Reporting Initiative* (GRI) report, disclosed by companies, as well as the completed Carbon Disclosure Project (CDP) official questionnaires, regarding the year 2015. The decision of using the sustainability report from the GRI was made because it has one of the most highly regarded standards for sustainability reports in the corporate world. The report from the CDP aims at facilitating the dialog between investors and corporations, organizing information of the participant companies regarding climate change strategies. In addition, these two reports are easily accessible and freely available to the public. In the GRI report, for instance, sections regarding climate risks are examined (G4-EC2). In CDP, climate risks information is found in section CC5.1 (CC5.1a, CC5.1b, CC5.1c). The final sample of companies used in this study is shown in Table 1.

After selecting the corporations in the Global Top 100 Companies by Market Capitalization, further research was done on the GRI site to locate sustainability reports presented by these companies. We verified that only 87 companies published reports. From Table 1, it can be observed that the objective of this study was to work with 100 companies (population), but due to lack of data, the final useful sample was 71 companies. For comparative purposes, we also collected the CDP reports of the 71 companies in question.

Table 1 Demonstration of sample selection process

No.	Sector	No. of companies in Global Top 100	No. of companies not on GRI database	Total no. of Global 100 that disclose GRI	On the database but did not disclose 2014 or 2015 GRI	Disclosed GRI but download impossible (not found)	Disclosed GRI but in another language	No. of final Reports for Content Analysis
1	Financial	19	3	16	1	2	4	9
2	Consumer goods	18	1	17	1	0	2	14
3	Healthcare	18	2	16	1	0	0	15
4	Technology	12	2	10	1	0	0	9
5	Consumer services	10	2	8	2	1	0	5
6	Oil and gas	9	2	7	0	0		7
7	Industrial	7	1	6	0	0	0	6
8	Telecommunication	4	0	4	0	0	0	4
9	Raw materials	3	0	3	0	0	1	2
Total		100	13	87	6	3	7	71

3.2 Key phrase search and content analysis

Content analysis was used in order to identify and quantify the information regarding climate risks in the selected reports. Content analysis required codification in qualitative and quantitative terms in previously defined categories in order to extract patterns in presentation and communication of information (Bardin 2011; Guthrie et al. 2004). Categorization of information regarding climate risks, described in Table 2, was performed using the following sources: (i) manual for implementing GRI 2015 guidelines, specifically topics G4-EC2—financial implications and other risks and opportunities for activities of the corporation due to climate change, (ii) CDP 2015 Manual, Risks and Opportunities section, Page CC5. Climate Change risks, (iii) documents from the Investor Network on Climate Risk (Ceres 2010), elaborated by CERES, (iv) Hague and Deign (2010), and (v) Doran and Quinn (2009). In Table 2, the framework of the content analysis is outlined.

As can be seen in Table 2, the framework is in four languages. This is because reports were published in these languages. However, almost 90% were published in English.

It is extremely important to remember that in this study research questionnaires were not applied, that is, questionnaires were not sent to companies to be responded to, nor were managers interviewed. Rather, it is a study based on company reports and documentation (CDP and GRI). The content analysis technique was applied to corporate sustainability reports to quantify the level of disclosure of climate risk.

3.3 Empirical context and statistical methods applied

3.3.1 Classical linear regression

In the literature on environmental disclosure, several studies have investigated the determinants of the level of corporate disclosure. In these studies, the *level of disclosure* represents the response variable. For modeling, the authors generally use linear regression. Nonetheless, the level of disclosure represented by the linear regression model may not be appropriate or recommended for the following three reasons:

(1) First, linear regression requires that the response variable be a continuous variable; however, the *level of disclosure* variable (sentence count) is not a continuous variable; it is by essence a discrete variable. (2) Secondly, the linear regression model requires the assumption of data normality, homoscedasticity ($\sigma 1^2 = \sigma 2^2 = \sigma 3^2 = \sigma n^2$), the fact that the *level of disclosure*

Table 2 Framework of the content analysis

English	Portuguese	French	Spanish
Regulatory Risk	Risco Regulatório	Risque Réglementaire	Riesgo Regulatorio
Physical Risk	Risco Físico	Risque Physique	Riesgo Físico
Competitive Risk	Risco Competitivo	Risque Concurrentiel	Riesgo Competitivo
Legal Risk	Risco Legal	Risque Juridique	Riesgo Legal
Reputational Risk	Risco de Reputação	Risque de Réputation	Riesgo de Reputación
Mitigation	Mitigação	Mitigation	Mitigación
Adaptation	Adaptação	Adaptation	Adaptación
Opportunities	Oportunidades	Opportunités	Oportunidades
Climate Risk	Riscos Climáticos	Risque climatique	El Riesgo Climático
Climate Changes	Mudanças Climáticas	Changements Climatiques	Cambios Climáticos

variable is discrete, means it is unlikely to have a normal distribution. (3) Thirdly, if researchers perceive that the variable does not follow a normal distribution (via a normality test of the histogram), most transform the variable by means of the logarithm neperian or using other forms of transformation, "forcing" the variable to follow a normal distribution. This procedure may impair the efficiency and effectiveness of the model because the original variable is not used. In these situations, what should be done? The literature provides alternatives for modeling if the data under analysis violate the assumptions or requirements of linear regression. Models referred to as alternatives to modeling the characteristics of a company that explain the disclosure level of climate risk include Generalized Linear Models (GLM) proposed by Nelder and Wedderburn (1972) described by Sant'Anna (2015).

3.3.2 Generalized Linear Models

The method used to choose the best regression model basically followed the structure proposed by Sant'Anna (2015). This author has developed a structure that serves researchers in the decision-making process by assisting them to choose the most appropriate regression model for data modeling. The method used by Sant'Anna (2015) was based on the most interesting and innovative regression models which were introduced by Nelder and Wedderburn (1972). These authors used the GLM class to model the relationship between a dependent variable and factors. This opened a range of options for probability distribution of the input variable, assuming that it belongs to the exponential distribution family (McCullagh and Nelder 1989 in Sant'Anna 2015). The systematic approach proposed by Sant'Anna (2015) provided clear orientation, with attention to details on how to choose the most appropriate regression model for modeling data according to the characteristics of the research variables. In addition, it addresses concepts that make experimental studies and the decision-making processes successful. The density probability function (dpf) of the exponential family is most commonly observed in the following equation:

$$f(y,\theta,\varnothing) = \exp\left[a(\varnothing)^{-1}-(y\theta-b\theta) + c(y\varnothing)\right] \tag{1}$$

where a, b, and c are known functions, θ is the location parameter, and $\phi > 0$ is the dispersion probability parameter.

Some advantages of using a GLM in comparison to the traditional model are more precise parameter estimation, modeling any probability distribution, precision in data analysis, non-orthogonal parameters of regression (β) and non-orthogonal precision (ϕ), and high precision in the presence of heteroscedasticity. The link function of a GLM is given as follows:

$$y = g^{-1}()\eta \tag{2}$$

$$y = g^{-1}\Big(\beta o + \beta 1\chi 1 + \beta 2\chi 2 + \ldots + \beta k\chi k + \varepsilon i \tag{3}$$

The procedures for performing the statistical tests in this study followed five steps:

Step 1: Define the variables in the experiment (identification and classification).
Step 2: Select the regression models.
Step 3: Apply criteria to choose the best model.

Step 4: Develop the modeling and parameter analysis.
Step 5: Develop the validation of the model.

The author emphasizes that these steps are designed to create a cycle of activities that drive the effectiveness and efficiency of the modeling experiment. In addition, the proposed structure was constructed from an extensive literature review in several areas of knowledge: administration, economics, medical science, engineering, and statistics in order to study the classifications used in articles and books, creating a standard and guiding the researcher to construct experimental models (Sant'Anna 2015).

It is important to remember, however, that we performed some preliminary tests such as descriptive statistics, standard deviation, median, coefficient of variation, outlier test, Pearson's correlation, and multicollinearity test among other crucial tests (see complementary document). In addition, the steps followed by the present study for statistical modeling are as follows:

Step 1: Define the variables in the experiment

According to the hypotheses established in this study, the variables are classified based on their type.

The response variable The response variable or the dependent variable, the amount of *climate risk disclosure* in the 100 largest companies' CDP and GRI reports, was quantified through content analysis. Thus, the variable response of this research is a variable classified as *quantitative and discrete*. It is discreet because it is obtained by counting the sentences in the disclosure reports (0, *n*). The independent variables in this paper are the six characteristics of the companies set out in the previous section (Section 2) that were analyzed to establish if there were relations with the response variable.

The independent variables were measured as follows:

- The variable *Size* represents the size of the company and was measured by the total assets of each company studied (Adams et al. 1998; Roberts 1992). It was classified as a *quantitative and continues* variable.
- The variable *Sector* represents the sector of activity of each company (Hackston and Milne 1996; Patten 1992). The dummy variable is defined as 1 if the company is of the sector in question and 0 for the other sectors. It was classified as a *qualitative* variable.
- The variable *Continent* represents the continent of the company: Europe, America, Oceania, and Asia. The dummy variable is defined as 1 when the company is from the continent in question and 0 for the other continents. This variable was classified as a *qualitative* variable.
- The variable *Efficiency* represents the size of the Board of Directors—that is, the number of people on the Board of Directors of the company (Amran et al. 2014). This variable was classified as a *quantitative discrete* variable.
- The variable *Women* represents the Proportion of women on the board which is obtained by the ratio between the number of women on the Board of Directors and the size of the Board of Directors (Amran et al. 2014). This variable was classified as a *quantitative* variable.

- The variable *Country* represents the country of origin of each company (Suttipun and Stanton 2012a). The dummy variable is defined as 1 if the country origin of the company is a "developed country" and defined as 0 if the country origin of the company is a "developing country." It is classified as a *qualitative* variable.

A summary of the search variables can be found in Table 3.

In order to verify the relationship between how characteristics of a company may influence climate risk information disclosure and also test the hypotheses, GLM were used. A description of the search variables can be seen in Table 3.

Based on Table 3, the econometric model constructed is presented as follows:

$$\text{Disclosure} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \varepsilon \quad (4)$$

where Disclosure = climate risk disclosure; $\beta 0$ = the constant; χ_1 = Size; χ_2 = Sector; χ_3 = Continent; χ_4 = Efficiency; χ_5 = Women; χ_6 = Country; $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$, and $\beta 6$ = the coefficients to be estimated and ε = the error. Each of the variables is described in Table 3.

Step 2: Select the regression models

After identifying and classifying all variables in this model, the next step is the selection of the regression model for the framework proposed by Sant'Anna (2015). According to Sant'Anna (2015), the GLM model encompasses several models—for instance, *Logistic model*, *Probit model*, *log-linear model*, *the Poisson's model*, *Negative Binomial model*, *β model*, *Gamma model*, *Weibull model*, *Inverse normal model* (or Inverse Gaussian), *Normal model* (or Gaussian), and *Lognormal model*.

As can be observed, the GLM data modeling developed by Nelder and Wedderburn in 1972 opens up a range of options so the researcher can model any kind of probability. What is important is the ability to identify the nature of the response variable. In this study, according to the proposed model, the response variable is the "level of disclosure." This variable was identified and classified as a discrete metric. Thus, according to the framework proposed by

Table 3 Variables and their measurement

Variables	Descriptions	Nature	Source
1. Response variable			
Disclosure	Level of disclosure of information on climate risks in GRI and CDP	Metric/discrete	Site of GRI and CDP
2. Independent variables			
Size	Size of the company measured by total assets	Metric	Financial reporting of companies
Sector	Classification of the company according to its economic activity	Qualitative	PwC website
Continent	Classification of the company by continent: Europe, America, Oceania, and Asia	Qualitative	PwC website
Efficiency	Number of people on the Board of Directors of the company	Metrics (ratio)	Company website
Women	Number of women on the board	Metrics	Company website
Country	Classification of companies in developed or developing country	Qualitative	UNCTA D/STAT

Sant'Anna (2015), three GLM options are candidates to model the data—normal model, log-linear model, and negative binomial model. The question remains: Which of these three models is the most appropriate for data modeling in this research?

Step 3: Criteria applied for choosing the best model

To identify the most appropriate model, the Omnibus test was performed and the fit quality of the three models in question was determined. The performance of a regression model is evaluated for the model's fit and adequacy (Sant'Anna 2015). The evaluation of the three candidate models in this study was made using the main diagnostic criteria, namely Deviance and Akaike information criterion (AIC).

- *Deviance*: This criterion is obtained by doubling the difference between the maximum log-likelihood of the null model and the saturated model:

$$D(y;\mu,\phi) = \Sigma_{i=1}^{n} 2\left[li\left(\tilde{u},\phi\right) - li\left(\hat{u},\phi\right)\right] \tag{5}$$

where $\tilde{u}$ is solution of $\partial li/\partial \mu i = 0$, i.e., $\varphi\ (yi^* - \mu i^*) = 0$, $li(\tilde{u}, \varnothing)$ is the maximum function likelihood of the model under study, and $li(\hat{u}, \varnothing)$ is the maximum likelihood function of null model. The analysis of deviance is usually done using the critical point $\chi 2(n-k)(\alpha)$ of the $\chi 2$ distribution. So, if $D(y; \mu, \phi) \leqslant \chi 2(n-k)(\alpha)$, there is evidence that the saturated model has a good fit (Riani and Atkinson 2000 in Sant'Anna 2015). Thus, there is evidence that the model under study is well adjusted to the data, at a level of α significance, usually $\alpha < 0.05$.

- *AIC*: This criterion was the first asymptotically unbiased criterion based on the Kullback-Leibler theorem. The AIC criterion assumes that the true model belongs to the set of candidate models and is defined by:

$$\mathrm{AIC} = -2li(\hat{u},\phi) + 2(k+1) \tag{6}$$

where $li(\hat{u}, \varnothing)$ is the maximum likelihood k function of the adjusted model and k the number of parameters. The AIC criterion was constructed using the maximum likelihood estimators to choose which model is most appropriate when there are many models with different numbers of parameters (Hurvich and Tsai 1995; apud Sant'Anna 2015). The decision regarding the best fit model is made by choosing the lowest AIC value (Sant'Anna, 2015). In order to diagnose the best model for modeling the data of this study, the test results of the three models can be seen in Table 4.

From Table 4, it can be observed that *negative binomial model* presented a chi-square of the likelihood ratio = 11.22, Deviance = 35.80, AIC = 549.61, and $df = 15$; p value > 0.05 demonstrates that it is not the appropriate model for data processing. Evaluating the *Normal* and *Poisson models*, we can see that the two models present better adjustments to the data when compared to the *negative binomial model*. Both presented p value < 0.05. Nonetheless, although the normal model presented an AIC = 561.34 which was less than the Poisson model's AIC = 701.64, it can be observed that the normal model presented a very large deviance denoting some discrepancies in this model (Deviance = 6989.2). Therefore, the best model for modeling the data in this research is the Poisson model.

Table 4 Adjustment quality and the Omnibus test

	Model		
	Normal	Poisson	Negative binomial
Chi-square of the likelihood ratio	42.03	267.2	11.22
Deviance	6989.2	379.43	35.8
Akaike Information Criterion (AIC)	561.34	707.64	549.61
Dimensional deviance	71	379.43	35.8
Pearson's chi-square	6989.2	376	26.69
Pearson chi-square scaled	71	376	26.69
Log-likelihood	(263.67)	(337.82)	(258.8)
Finite sample corrected AIC (AICC)	572.89	717.71	559.68
Bayesian Information Criterion (BIC)	599.81	743.84	585.81
Consistent AIC (CAIC)	616.81	759.84	601.81

Normal model: Chi-square of the likelihood ratio = 42.03; Deviance = 6989.2; AIC = 561.34; $df = 15$; $p < 0.01$.
Poisson model: Chi-square of the likelihood ratio = 267.2; Deviance = 379.43; AIC = 707.64; $df = 15$; $p < 0.01$.
Negative binomial model: Chi-square of the likelihood ratio = 11.22; Deviance = 35.80; AIC = 549.61; $df = 15$; $p > 0.05$

df degree of freedom

It is important to note that *chi-square of the likelihood ratio* is similar to the R^2 of linear regression models but bigger and better. Thus, the Poisson model is the best fit of the three models for data modeling at the expense of the negative binomial and normal model. The criteria considered to evaluate the models suggest that the structure of the most appropriate and compatible regression model is the Poisson model, possibly due to the performance of the probability density function. According to literature, this is because the Poisson model is used in studies in which the response or dependent variable has discreet values (Sant'Anna 2015). The response variable in this study is obtained by counting sentences in sustainability reports. Thus, the most suitable model for modeling the data was the *Poisson model*. The binding function of the Poisson model is:

$$y = \log(\mu) = \beta 0 + \sum_{j=1}^{p} \beta j \chi j + \varepsilon \tag{7}$$

where y is the response variable, $\beta 0$ a constant, βi coefficients of the independent variables to be estimated, χj variables, and εi the error term. Table 5 presents the Poisson model effect test.

Table 5 Model effect tests

Variables	Wald's chi-squared	*df*	Sig. (*p* value)
(Sorted by origin)	437.528	1	0.000
Size	33.896	1	0.000
Sector	52.881	8	0.000
Region/continent	64.060	3	0.000
Efficiency	18.518	1	0.000
No. of women	13.706	1	0.000
Country status	00.840	1	0.359

Response variable: climate risk disclosure

df degree of freedom

Table 5 presents the Poisson test results. All the variables were statistically significant (p value = 0.000 < 0.01) with the exception of the "country status" variable. This result demonstrated, once again, that the Poisson method is the best suited for the statistical treatment of the research data.

4 Results

4.1 Descriptive statistics

4.1.1 Disclosure of climate risks in the sustainability report (GRI)

Table 6 shows the total number of sentences found in sustainability reports from the investigated companies by sector.

A total of 600 sentences were found, of which 142 sentences were found in the "Technology" sector, representing almost 24% of the total. The sector with the second highest rate of disclosure was the "Consumer goods" sector, followed by the "Financial" sector. The sector with the least disclosure was "Telecommunications." When analyzing disclosure by sector, it was found that the "Financial" sector had the highest rate of disclosure regarding "climate risks." Also, the "Raw materials" sector disclosed the highest amount of information about "Physical risk."

It was observed that TSMC—a Taiwanese company from the "Technology" sector—disclosed most information related to climatic risks in the 2015 GRI. During the analysis of this company's report, it was found that it had clearly detailed separate topics such as strategies, actions, and policies for mitigating climate risks. This may be considered a good example to be followed by other companies. The company with the second highest level of disclosure was BHP Billiton, from the "Raw materials" sector, in Australia. From the 71 companies that published the sustainability GRI report, eight of them did not provide information regarding policies, actions, and strategies for mitigating the effects of climate change. The corporations that did not present any information on climate risks in their GRI reports are shown in Table 7.

4.1.2 Disclosure of climate risk in CDP questionnaire

Of the 71 companies, 10 did not respond to climate risks issues representing 14%. The corporations that did not present any information on climate risks in their CDP reports are shown in Table 8.

Table 8 shows eight companies that did not address any issues regarding climate risks (questionnaire CC5.1). On the other hand, two companies mentioned the three big risk categories (CC5.1—see Table 9) in their reports; however, they did not discuss anything regarding such items. In other words, they did not comment on questions CC5.1a, CC5.1b, and CC5.1c of the CDP. The results of the content analysis on climate risks from CDP questionnaires answered by the studied companies are listed in Table 9. A total of 447 sentences about climate risks were found in the CDP questionnaires.

From the results, it appears that the "Regulatory risks" category was the most predominant one, representing about 47%, almost half of all information related to

Table 6 Results of the content analysis in GRI reports

Sector/themes	Regulatory risk	Physical risk	Competitive risk	Legal risk	Reputational risk	Mitigation	Adaptation	Opportunities	Climate risk	Climate change	Total	*N* (no. of companies)	Mean
Technology	7	5	3	8	1	22	9	18	23	46	142	9	9.0
Consumer goods	6	1	1	0	1	19	13	3	27	55	126	14	9.0
Financial services	0	0	0	0	2	7	3	7	32	37	88	9	9.8
Raw materials	1	5	0	0	0	5	10	8	20	8	57	2	2.0
Healthcare	2	2	0	0	0	5	1	3	3	36	52	10	5.2
Oil and gas	3	1	0	0	0	6	2	3	10	20	45	7	6.4
Industry	1	0	0	0	0	2	0	2	8	25	38	4	9.5
Consumer services	0	1	0	0	0	3	1	5	7	20	37	4	9.3
Telecoms	0	0	0	0	0	3	1	1	1	9	15	4	3.8
Total	20	15	4	8	4	72	40	50	131	256	600	63	9.5
N	14	8	3	2	4	35	14	21	60	28	189		
Mean	1.43	1.88	1.33	4.00	1.00	2.06	2.86	2.38	2.18	9.14	3.17		

Table 7 Companies that made no disclosure of climate risks in their GRI reports in 2015

No.	Rank (PwC 2015)	Company	Sector	Country	Disclosure
1	13	General Electric	Industrial	USA	0
6	31	Walt Disney	Consumer service	USA	0
3	45	Gilead Science	Healthcare	USA	0
8	48	Novo Nordisk	Healthcare	Denmark	0
4	66	UnitedHealth Group	Healthcare	USA	0
2	71	United Technologies	Industrial	USA	0
5	86	AbbVie Inc	Healthcare	USA	0
7	97	AstraZeneca PLC	Healthcare	UK	0

climate risk disclosure; next was the "Physical risks" category, which made up 32%; and finally, the "Other risks" category, represented 21% of the total disclosed. From the results, it also appears that the phrase that appeared most in the analyzed questionnaires was "risk to reputation," here representing the risk that the company's image would have in the face of challenges posed by climate change. This demonstrates that companies are very worried about how their different stakeholders perceive them—a group made up of investors, shareholders, government, and society as a whole.

We found that the level of disclosure in the CDP questionnaire responses with regard to climate risk varies from sector to sector and by category of climate risk. The "Oil and gas" sector disclosed the most amount of information about climate risks. This is consistent with previous research, which claims that high-profile companies are those that operate in highly persistent industries (Perry and Sheng 1999; Stray and Ballantain 2000; Suttipun and Stanton 2012b) and are therefore more vulnerable to political and social environmental issues than low-profile businesses (Newsone Deegan 2002).

The "reputation" of a corporation is strongly linked to the vision that society has of it particularly in relation to climate change and climate risks. This reinforces one of the assumptions of legitimacy theory, according to which there is a kind of contract between the company and the society in which it operates (Suchman 1995; Deegan 2002, 2006, 2007a; Gray et al. 1995). Furthermore, the company must produce internal boundaries, respecting values and limits when carrying out its activities, and disclosure is a way or channel that companies use to communicate with society.

The degree of disclosure to the CDP questionnaires, regarding climate risks, was found to vary from one activity sector to another and by category of climate risks. Table 10

Table 8 List of CDP reports with no disclosure of climate risks

Ranking (PwC 2015)	Company name	Sector	Country
6	PetroChina Ltd	Oil and gas	China
13	General Electric	Industrial	USA
73	Boeing Co.	Industrial	USA
83	Siemens AG	Industrial	Germany
19	Procter & Gamble	Consumer goods	USA
33	Coca Cola	Consumer goods	USA
45	Gilead Science	Healthcare	USA
68	Medtronic PLC	Healthcare	Ireland
64	Qualcomm Inc.	Technology	USA
93	SAP AG	Technology	Germany

Table 9 Results from content analysis of the CDP reports

Categories of climate risks	Subcategories of climate risks	Disclosure	Classification
Risks driven by changes in regulation	Cap and trade schemes	28	3rd
	Carbon taxes	26	4th
	Fuel/energy taxes and regulations	23	5th
	Uncertainty surrounding new regulations	22	6th
	Emission reporting obligations	19	8th
	General environmental regulations, including planning	19	9th
	International agreements	13	12th
	Other regulatory drivers	12	14th
	Product labeling regulations and standards	11	15th
	Air pollution limits	10	18th
	Product efficiency regulations and standards	9	20th
	Renewable energy regulation	6	25th
	Lack of regulation	5	28th
	Voluntary agreements	4	29th
Total		211	
Risks driven by changes in physical climate parameters	Rise in sea level	11	16th
	Changes in precipitation, floods, and droughts	34	2nd
	Tropical cyclones (hurricanes and typhoons)	19	10th
	Uncertainty of physical risks	19	11th
	Change in precipitation pattern	13	13th
	Change in mean (average) temperature	11	17th
	Other physical climate drivers	10	19th
	Change in temperature extremes	7	23rd
	Induced changes in natural resources	6	26th
	Change in mean (average) precipitation	6	27th
	Snow and ice	2	32nd
Total		143	
Risks driven by changes in other climate-related developments	Reputation	35	1st
	Changing consumer behavior	22	7th
	Uncertainty in market signals	8	21st
	Other drivers	8	22nd
	Fluctuating socioeconomic conditions	7	24th
	Uncertainty in social drivers	4	29th
	Increasing humanitarian demands	3	31st
	Induced changes in human and cultural environments	2	32nd
Total		93	
Total global		447	

demonstrates the climate risk disclosure by activity sector and the ranking of companies, considering the categories of climate risks:

It can be seen that, on average, the differences in the disclosure level of information about climate risks between both reports were insignificant. The disclosure of CDP had a total of 447 sentences with an average of 7.58, while the disclosure of GRI totaled 475—excluding the outliers from the standard calculation—with an average of 7.79.

Table 10 Detailed results by category of climate risks/sectors

Categories	Risks driven by changes in regulations				Risks driven by changes in physical climate parameters				Risks driven by changes in other climate-related developments				Results considering all categories combined together			
Sector	Total	*N*	Mean	Ranking	Total	*N*	Mean	Rank	Total	*N*	Mean	Rank	Total	*N*	Overall mean	Ranking
Oil and gas	27	6	4.50	1st	12	5	2.40	5th	11	6	1.83	6th	50	17	2.94	3rd
Technology	27	7	3.86	3rd	10	5	2.00	7th	12	5	2.40	3rd	49	17	2.88	5th
Financial	25	7	3.57	4th	20	9	2.22	6th	11	8	1.38	7th	56	24	2.33	7th
Industrial	5	3	1.67	9th	6	3	2.00	7th	2	2	1.00	9th	13	8	1.63	9th
Consumer goods	36	12	3.00	6th	29	12	2.42	4th	22	11	2.00	4th	87	35	2.49	6th
Healthcare	58	13	4.46	2nd	35	11	3.18	3rd	19	7	2.71	1st	112	31	3.61	1st
Telecoms	14	4	3.50	5th	16	4	4.00	2nd	5	4	1.25	8th	35	12	2.92	4th
Consumer services	13	5	2.60	8th	10	5	2.00	7th	6	3	2.00	4th	29	13	2.23	8th
Raw materials	6	2	3.00	6th	5	1	5.00	1st	5	2	2.50	2nd	16	5	3.20	2nd
Total	211	59	3.58		143	55	2.60		93	48	1.94		447	162	2.76	

The results reveal that, considering all consolidated sectors, the level of disclosure varied little.

On the other hand, the "Industry" and "Consumer services" sectors showed a slightly more significant difference between the two reports. While in CDP the averages were 4.33 and 5.80, respectively, in GRI, they were 9.5 and 9.25, respectively. According to these findings, companies from the "Industry" and "Consumer Services" sectors disclosed more information regarding climate risks in the GRI sustainability report than in the CDP questionnaire. However, the "Health" and "Raw materials" sectors had the opposite results. That is, there was more information regarding climate risks in the CDP questionnaires than in the GRI sustainability reports.

Consolidating information from both reports, the sector with the greatest level of disclosure was the "Financial" sector, with an average of nine sentences per report. The second sector with a high level of disclosure was "Consumer goods," with an average of 8.26 sentences per report. The third sector with a high level of disclosure was "Technology," with an average of 8.07 sentences per report.

4.2 Hypothesis testing

Step 4: Develop the modeling and parameter analysis

Presented in detail in Section 3, the most suitable final model for modeling the data was the Poisson model. The final parameter estimation results of the research model equation are shown in Tables 11 and 12.

The Poisson model regression uses logarithms to estimate the coefficient variables; for this reason, after estimating this model's coefficients, it was necessary to transform these coefficients back to their original values via exponential conversion.

The variable "size" had a p value = 0.000 with a coefficient of exp [0.000] = 1.000. This showed that there were no positive or negative relationships between the level of disclosure regarding climate risks and the size of the company, parameterized by total assets, leading to the rejection of hypothesis *H1*. According to Suttipun and Stanton (2012), the theory of legitimacy suggests that large companies should respond with more disclosure because they have a greater impact on social expectations, since they have

Table 11 Mean comparison of disclosure by sector

	CDP Report			GRI Report			CDP and GRI		
Sector	CDP	*N*	Mean	GRI	*N*	Mean	Total	*N*	Mean
Oil and gas	50	6	8.33	45	7	6.43	95	13	7.31
Technology[a]	49	7	7.00	72	8	9.00	121	15	8.07
Financial	56	7	8.00	88	9	9.78	144	16	9.00
Industrial	13	3	4.33	38	4	9.50	51	7	7.29
Consumer goods	87	12	7.25	126	14	9.00	213	26	8.19
Healthcare	112	13	8.62	52	10	5.20	164	23	7.13
Telecoms	35	4	8.75	15	4	3.75	50	8	6.25
Consumer services	29	5	5.80	37	4	9.25	66	9	7.33
Raw materials[a]	16	2	8.00	2	1	2.00	18	3	6.00
Total	447	59	7.58	475	61	7.79	922	120	7.68

Table 12 Regression results

	Expected sign	Estimate	*df*	Standard error	*p* value
Intercept		3.491		0.3292	0.000
Size	+	0.000		0.0000	0.000
Sector	−/+	52.88		–	0.000
Raw materials	+	0.173	1	0.2425	0.477
Consumer goods	+	0.319	1	0.1609	0.047
Consumer services	+	0.073	1	0.1916	0.702
Financial services	–	− 1.061	1	0.2688	0.000
Healthcare	–	− 0.031	1	0.1637	0.849
Industry	+	− 0.140	1	0.2030	0.490
Oil and gas	+	− 0.118	1	0.1817	0.517
Technology	–	0.320	1	0.1691	0.062
Telecommunications	–	0			
Continent		64.060		–	0.000
America	−/+	− 1.274	1	0.2058	0.000
Asia	−/+	0.563	1	0.2937	0.055
Europe	−/+	− 1.156	1	0.2065	0.000
Oceania	−/+	0[a]			
Efficiency of BD	–	− 0.038	1	0.0089	0.000
Number of women in BD	+	1.181	1	0.3190	0.000
Country					
Developed	+	0.25	1	0.2734	0.359
Developing		0[a]			

BD Board of Director

[a] Set to zero because this parameter is redundant

more stakeholders than small ones. However, the results of this study could not confirm any such relationship. Nevertheless, this finding can be explained by the research sample characteristics, because the survey sample was composed of the largest 100 companies in the world. The average difference between sizes tends to be insignificant when it comes to influencing the level of disclosure. Therefore, we cannot reject the assumption of legitimacy theory that size influences disclosure. In fact, for this reason, certain control variables, such as financial performance and indebtedness, were not investigated, taking into consideration the specific characteristics of the sample.

The variable "sector" had a *p* value = 0.000, indicating that the company's activity sector impacts its level of information disclosure regarding climate risks, which in fact is consistent with hypothesis *H2*. This finding corroborates the results of Stanwick and Stanwick (2000) and Hackston and Milne (1996). It is inferred that companies operating in economic activities considered to be potentially polluting and which are able to modify the environment are more likely to disclose environmental information than those with low polluting potential activities.

Analyzing sectors specifically, we observed that the "Financial" sector is the one with a stronger negative coefficient of *exp* [− 1061] = 0.346, statistically significant at a level of 1% (*p* value = 0.000)—revealing that companies in the "Financial" sector are 65.4% (1–0.346) less likely to disclose climate risk information than the average of the top 100 companies. The "Consumer goods" sector was statistically significant at the 5% level (*p* value = 0.047) with a coefficient of *exp* [0.319] = 1.376, positively denoting that companies in this sector tend to disclose more information about climate risks. This means that "Consumer goods" companies are 37.6% more likely to report climate risk disclosure. In

the "Technology" sector, the results are also statistically significant (p value = 0.06), with a coefficient of exp [0.32] = 1.37—a positive signal, revealing that there is a positive relationship between the "Technology" sector and the information disclosure level of climate risk. Therefore, these results confirm hypothesis *H2*.

The "Country" variable had a p value = 0.359, demonstrating the non-existence of statistically significant differences between the level of climate risk disclosure of companies from developed countries and those from emerging countries. As a result, hypothesis *H3*—that companies from developed countries have a higher information disclosure level regarding climate risks than companies from emerging countries—was rejected. This finding diverges from results found by Adams et al. (1998) and Kolk et al. (2001).

The "Continent" variable, in a generic way, gave a p value = 0.000, showing that this variable is a determining aspect regarding the level of information dissemination of climate risk. America and Europe were statistically significant at the 1% level (p value = 0.000), with coefficients of exp [− 1274] = 0.279 and exp [− 1156] = 0.314, respectively. These results show that companies from the USA and Europe, on average, reported 72.10% (0.279–1) and 68.6% (0.314–1) less climate risk information, respectively, considering the average disclosure level of all continents.

The Asian continent had a positive relationship with the level of disclosure, with a coefficient of exp [0.563] = 1.756 statistically significant at the level of 5% (p value = 0.05), revealing that companies from Asia tend to disclose more information regarding climate risk than companies from other continents. That is, Asian companies had on average 75.6% greater disclosure of information on climate risks when compared to the level of disclosure across all continents.

The Board of Directors' efficiency, parameterized by its size, had a strong negative relationship with a coefficient of exp [0.038] = 0.962—it was statistically significant at the level of 1% (p value = 0.000), regarding climate risk information disclosure. This result led to the acceptance of hypothesis *H5*. This result reveals that Board of Directors of small size—in other words, efficient ones—have a stronger commitment to climate issues. This result confirms predictions from authors Lipton and Lorsh (1992) and Jensen (1993) that an efficient Board of Directors should be small.

The "proportion of women on the Board of Directors" variable had a strong positive relationship, with a coefficient of exp [1.181] = 3.257, statistically significant at the level of 1% (p value = 0.000) for the climate risk information disclosure level. This leads to the acceptance of hypothesis *H6*—that is, the greater the proportion of women on the company's Board of Directors is, the higher the commitment with issues regarding climate change and, consequently, the higher the information disclosure level. For each additional female Board of Director member, the company's level of disclosure increased 225.7% (3257–1).

Step 5: Validation of model

In order to validate the model used to represent the data of this research, the following diagnostics were performed:

- *Standardized residuals*: The residues are usually used in the model's adequacy diagnosis plotting these residuals. This graphical tool is useful when evaluating the adequacy of models, randomness of residuals, probability distribution of response variable, and inclusion of new factors or outliers (Rao and Wu, 2005 in Sant'Anna 2015).

- *Deviance residuals*: according to Sant'Anna, (2015), this is the most recommended residual in graphical analysis/diagnosis because these residues are the closest to the Normal probability distribution to verify the adequacy to the role of probability and randomness of the residues.

Finally, the diagnostic measures proposed in this paper to analyze and validate the adequacy of the regression models are presented in Figs. 1 and 2.

From Figs. 1 and 2, it can be observed that the residues are within the range, showing that the binding function used is perfectly suitable for data modeling. Furthermore, the residues show no tendency. On the contrary, they appeared random and there were no extreme values or outliers.

4.3 Contributions, limitations, and future research

The efforts by corporations in carbon management play an important role in mitigating greenhouse gas emissions to consequently reduce climate risks, but very little previous research focused on the climate risk disclosure. First, the present study contributes to the literature that deals with corporate disclosure, more particularly, the disclosure of climate risks. The management of climate risks in the business context is a current topic of great importance. In fact, there is a desperate need for companies to better understand their climate risks and for investors and others to understand the potential climate risks on their investments. This study presents a way to get people thinking more about the evaluation of risk disclosure. The results provided some insight into how companies are committed to climate issues and how they are disclosing them in sustainability reports as a form of accountability to the various stakeholders. In addition, the results of this study revealed that when the level of disclosure is relatively low, it might be a warning sign to companies that they are vulnerable to climate risks, especially regulatory ones.

Nevertheless, in pointing out the contribution that this study makes to the literature on corporate disclosure, it is important to recognize some important limitations, in particular the sample size. The initial population of 100 companies was reduced to 71 due to accessibility and non-conformance of the reports in order that the content analysis could be performed. The ability of this study to analyze and examine climate change was also limited by the fact that only 1 year of study could be considered. In addition, the research worked with climate disclosure information reported by the companies. Therefore, a few questions need to be addressed. Is the "climate risk disclosure" that companies are currently doing today really accurate and transparent? Or is it nothing more than green washing? Is it based on serious analysis, scenario planning, or even rudimentary risk assessment? Or is it simply done for purposes of informing organizations such as GRI

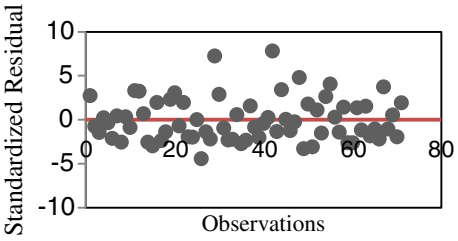

Fig. 1 Figure of standardized residuals

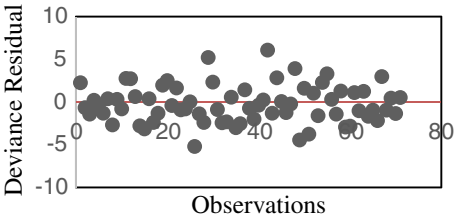

Fig. 2 Figure of deviance residual

and CDP to get a better score or its equivalent? Thereby, analyzing the context, it is reasonable to believe that even if companies are making a serious assessment of climate risk, they are unlikely to disclose all information for competitive reasons.

As a result, the more companies take climate risks seriously, the more likely it is that this information will be concealed. In addition, the results are valid only for the companies analyzed and therefore cannot be generalized to all companies in the world as it is a small sample. The results achieved in this study should be examined carefully and can be considered as very preliminary for future studies.

Finally, investigating the disclosure of information on climate risks is a promising area for future research, given that companies have a very important role to play in this process of mitigating climate change. Investigating the largest companies in the world is even more relevant because they have the resources to invest in such issues as well as serving as an example for small- and medium-sized enterprises. A future study could explore the long-term trends of the world's largest companies, incorporating future cycles of CDP survey responses.

5 Conclusions and implications

Climate change represents an urgent threat with potentially irreversible impact for humankind and the planet. Therefore, it requires broader participation from all countries. This participation requires an effective and proper response in order to accelerate the reduction of greenhouse emissions (GEE) (IPCC 2014). Thus, this subject currently occupies important places on prominent agendas and is being discussed by the governments, environmental organizations, international organizations, and society as a whole.

This study aimed to investigate if there are statistically significant relationships between the disclosure of information about climate risks and its determinants by the *Global Top 100 Companies by Market Capitalization*, according to the classification of PwC. In order to achieve this objective, the paper analyzed the reports from the GRI and the CDP questionnaires answered by those companies. From 100 companies, 13 are not in the GRI database, three did not disclose the reports in a format appropriate to perform the content analysis, and seven companies released reports in languages unknown to the researchers. Thus, the final sample of this study was composed of 71 corporations.

Using content analysis, the research identified 600 sentences in the GRI sustainability reports about climate risks. The sectors with the largest disclosure on average were Technology, Consumer goods, and Finance. The words "Climate Change" and "Climate Risks" were found to be the ones used most often by the investigated companies. Companies such as "TMSC" from Thailand, followed by "BHP Billiton" from Australia and "Nestlé S.A." disclosed large amounts of information about phenomena related to climate change,

respectively. On the other hand, this study found eight companies that did not disclose any Climate Change information in their sustainability reports.

Results from the content analysis of CDP questionnaires identified that ten sampled companies did not answer the question regarding climate risks. Some mentioned in their reports that economic activity is not subject to climate risks. There were 447 sentences regarding climate risks. The "Regulatory risks" category was the most predominant, representing nearly 47%, followed by the "Physical risks" category with 32% and in last place the "Other risks" category representing 21% of the total disclosure. Results demonstrated that the "Oil and gas" sector provided more information about regulatory risks than other sectors. Considering the "Physical risks" category, the sector with the highest disclosure was "Raw materials," and finally, considering the "Other risks" category, the sector that stood out was "Health."

The study demonstrates that the level of concern regarding questions linked to climate change is lower than what was expected. From 71 companies, only two disclosed information on climate risks above 65 sentences, representing 2.81% of the sampled companies. Only five companies disclosed between 25 and 50 sentence units of information and more than 78% disclosed less than 20. Why did 2.81% of companies disclose more than 65 units of information regarding climate risks, while 78% disclosed less than 20 and others disclosed absolutely nothing about climate risks? Are those companies not concerned about the challenges related to climate change? If many of the largest companies in the world, taking into consideration their capital power, take little action and do not have strategies to mitigate the challenges and consequence of climate change, what about smaller companies?

Regarding the sixth research hypotheses, two of them were rejected. Analyzing the results, it is possible to infer that company size has no impact on disclosure level of climate risks; however, more research is required. Results also indicate that the company's region or continent is strongly related with the level of disclosure of climate risks. In addition, the results demonstrate that Asian companies tend to disclose more information on this subject than companies from other continents. This may be related to the vulnerability level of each continent regarding climate change consequences. The study also revealed that whether or not a company's origin was a developed or undeveloped country had no effect on its level of disclosure regarding climate risks. On the other hand, it seems that a company's specific country of origin influences disclosure level. This may be related with current rules regarding climate change in a country. For instance, if the Australian government has strong legislation on climate change, it is clear that companies from that country will disclose more information.

It was found that the higher the number of women on a company's Board of Directors, the greater a company's commitment and disclosure would be regarding climate issues. We conclude that information disclosure is a very important component in the climate mitigation process and it is also becoming very important for investors when making investment decisions. An important conclusion is that the influence of investors as shareholders and suppliers of capital, and the power of governments is necessary to increase the level of a company's commitment on climate issues and, as a consequence, increase the disclosure of such information.

This study provides some empirical evidence for scholars, students, researchers, academics, and professionals of the extent and content of climate risk disclosure by the world's largest companies and extends the findings, discussions, and debates of previous studies about corporate climate risk disclosure. The results of this study may encourage governments of all countries investigated to make corporate environmental

reporting mandatory in the future. Furthermore, governments should provide stronger public policy to engage corporations to reduce emissions. Thus, our findings may serve as a basis for decision-making by country leaders, especially the environmental agencies considering legislation on climate change.

Given the low level of disclosure found in this study, companies are at serious threat of facing regulatory risks. Since the absence or lack of information disclosed on climate risks can be interpreted by environmental agencies or governments as a lack of commitment to limit emissions. One strategy demonstrated by the present study to increase the level of disclosure of climate risks is that companies should increase the participation of women on the Board of Directors. Another strategy to increase climate risk disclosure may come from the strength of institutional investors and governmental regulation. These stakeholders can put pressure on companies to increase their commitment to climate issues.

Finally, the world's largest companies should proactively identify the specific climate risks to which their business is subject. They should develop actions, policies, and strategies to mitigate risks related to climate change. These actions should be reported and disclosed as a form of accountability to stakeholders. In the current context of emission reduction targets, detailed disclosure of mitigation strategies is crucial as it provides greater security for investors, governments, and the wider community. Thus, the world's largest companies should lead by example and make greater investments in climate risk disclosure.

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References

Adams CA, Hill WY, Roberts CB (1998) Corporate social reporting practices in Western Europe: legitimating corporate behavior? Br Account Rev 30(1):1–21. https://doi.org/10.1006/bare.1997.0060

Aerts, W., Cormier, D., & Magnan, M. (2004). Environmental disclosure by continental European and North American firms: contrasting stakeholders' claims and economic consequences. Working Paper, École des Sciences de la Gestion Université du Québec à Montréal. Montreal, Quebec

Amran A, Periasamy V, Zulkafli AH (2014) Determinants of climate change disclosure by developed and emerging countries in Asia Pacific. Sustain Dev 22(3):188–204. https://doi.org/10.1002/sd.539

Baginski SP, Hassell JM, Kimbrough MD (2002) The effect of legal environment on voluntary disclosure: evidence from management earnings forecasts issued in US and Canadian markets. Account Rev 77(1):25–50. https://doi.org/10.2308/accr.2002.77.1.25

Bardin L (2011) Content analysis. São Paulo: Editions 70

Bierbaum R, Smith JB, Lee A, Blair M, Carter L, Chapin FS et al (2013) A comprehensive review of climate adaptation in the United States: more than before, but less than needed. Mitig Adapt Strateg Glob Chang 18(3):361–406. https://doi.org/10.1007/s11027-012-9423-1

Boiral O, Henri JF, Talbot D (2012) Modeling the impacts of corporate commitment on climate change. Bus Strateg Environ 21(8):495–516. https://doi.org/10.1002/bse.723

Böttcher CF, Müller M (2015) Drivers, practices and outcomes of low-carbon operations: approaches of German automotive suppliers to cutting carbon emissions. Bus Strat Env 24(6):477–498. https://doi.org/10.1002/bse.1832

Brammer, S. and Pavelin, S. (2006) Voluntary environmental disclosures by large UK

Broder, J. M. (2010). SEC adds climate risk to disclosure list. New York Times, 27

Brown N, Deegan C (1998) The public disclosure of environmental performance information—the dual test of media agenda setting theory and legitimacy theory. *Accounting and Business Research* 29(1):21–41 *Capital* 5, 2: 282–93

Byard D, Shaw KW (2003) Corporate disclosure quality and properties of analysts' information environment. Journal of Accounting, Auditing & Finance 18(3):355–378. https://doi.org/10.1177/0148558X0301800304

Carter DA, Simkins BJ, Simpson WG (2003) Corporate governance, board diversity, and firm value. Financ Rev 38(1):33–53. https://doi.org/10.1111/1540-6288.00034

CDP - Carbon Disclosure Project (2015) Guidance for companies reporting on climate change on behalf of investors & supply chain members 2015. Available in: https://www.globalreporting.org/resourcelibrary/GRIG4-Part1-Reporting-Principles-and-Standard-Disclosures.pdf. Access in March 2016

Ceres, Investor Network on Climate Risk (2010) Climate Change Risk Perception and Management: A Survey of Risk Managers. April 2010. A Ceres Report. Sponsored by Zurich. In association with PRMIA. Available in http://www.ceres.org Access in December 2014

Chakrabarty S, Wang L (2013) Climate change mitigation and internationalization: the competitiveness of multinational corporations. Thunderbird International Business Review 55(6):673–688. https://doi.org/10.1002/tie.21583

Cho CH, Patten DM (2007) The role of environmental disclosures as tools of legitimacy: a research note. Acc Organ Soc 32(7):639–647. https://doi.org/10.1016/j.aos.2006.09.009

Cho CH, Guidry RP, Hageman AM, Patten DM (2012) Do actions speak louder than words? An empirical investigation of corporate environmental reputation. Acc Organ Soc 37(1):14–25. https://doi.org/10.1016/j.aos.2011.12.001

Clarkson PM, Li Y, Richardson GD, Vasvari FP (2008) Revisiting the relation between environmental performance and environmental disclosure: an empirical analysis. Acc Organ Soc 33(4):303–327. https://doi.org/10.1016/j.aos.2007.05.003

Cooke TE, Wallace RO (1990) Financial disclosure regulation and its environment: a review and further analysis. J Account Public Policy 9(2):79–110. https://doi.org/10.1016/0278-4254(90)90013-P

Cormier D, Magnan M (1997) Investors' assessment of implicit environmental liabilities: an empirical investigation. J Account Public Policy 16(2):215–241. https://doi.org/10.1016/S0278-4254(97)00002-1

Cotter J, Najah MM (2012) Institutional investor influence on global climate change disclosure practices. Aust J Manag 37(2):169–187. https://doi.org/10.1177/0312896211423945

Cowen SS, Ferreri LB, Parker LD (1987) The impact of corporate characteristics on social responsibility disclosure: the typology and frequency-based analysis. Acc Organ Soc 12(2):111–122. https://doi.org/10.1016/0361-3682(87)90001-8

Da Silva Gomes, S. M., Koulou Koui, D., Leal Bruni, A., & Cruz Oliveira, N. (2017). relação entre o disclosure de riscos climáticos e o retorno anormal das empresas brasileiras. Revista Universo Contábil, ISSN 1809-3337 Blumenau, v. 13, n. 2, p. 149–165 http://www.redalyc.org/articulo.oa?id=117051921009. https://doi.org/10.4270/RUC.2017213

Dawkins C, Fraas JW (2011) Coming clean: the impact of environmental performance and visibility on corporate climate change disclosure. J Bus Ethics 100(2):303–322. https://doi.org/10.1007/s10551-010-0681-0

De Aguiar, T. R. S., & Bebbington, J. (2014). Disclosure on climate change: analyzing the UK ETS effects. In *Accounting Forum* (Vol. 38, no. 4, pp. 227-240). Elsevier

Deegan C 2006. Financial Accounting Theory, second ed. McGraw-Hill Irwin, Sydney

Deegan C (2007) Organizational legitimacy as a motive for sustainability reporting. In: Unerman J, Bebbington J, O'Dywer B (eds) Sustainability accounting and accountability. Routledge, London

Deegan C, Gordon B (1996) A study of the environmental disclosure practices of Australian corporations. Account Bus Res 26(3):187e199

Deegan C, Rankin M (1996) The Australian companies report environmental news objectively? Accounting, Auditing and Accountability Journal 9(2):50–67. https://doi.org/10.1108/09513579610116358

Doran, K. L., & Quinn, E. L. (2009). Climate change risk disclosure: a sector by sector analysis of SEC 10-K filings from 1995–2008

Doran, K. L., Quinn, E. L., & Roberts, M. G. (2009). Reclaiming transparency in a changing climate: trends in climate risk disclosure by the S & P 500 from 1995 to the present. Center for Energy & Environmental Security

Dowling J, Pfeffer J (1975) Organizational legitimacy: social values and organizational behavior. Pacific Sociological Review 18(1):122e137

Entwistle GM (1999) Exploring the R&D disclosure environment. Account Horiz 13(4):323–342. https://doi.org/10.2308/acch.1999.13.4.323

Fama EF (1980) Agency problems and the theory of the firm. J Polit Econ 88(2):288–307. https://doi.org/10.1086/260866

Fama EF, Jensen MC (1983) Separation of ownership and control. The Journal of Law and Economics 26(2):301–325. https://doi.org/10.1086/467037

Fordham J. Corp. & Fin. L. 281 (2008–2009) Warming up to climate change risk disclosure. McFarland, J. M. *14*, 281

Frankel R, McNichols M, Wilson G (1995) Discretionary disclosure and external financing. *The*. Account Rev 70(1):135–150 Retrieved from http://www.jstor.org/stable/248392

Fried D (1984) Incentives for information production and disclosure in a duopolistic environment. Q J Econ 99(2):367–381. https://doi.org/10.2307/1885531

GICCC - Global Investor Coalition on Climate Change (2013) Global investor survey on climate change, 3rd Annual report on actions and progress Commissioned by the networks of the global investor coalition on climate change. Avaiable in: http://www.iigcc.org/files/publication-files/2013_Global_Investor_Survey_Report_Final.pdf. Access in April 2016

Gray R, Kouhy P, Lavers S (1995) Main themes: constructing the research database of social and environmental reporting by UK companies. *Accounting, auditing and accountability Journal* 8(2):78–101. https://doi.org/10.1108/09513579510086812

GRI - Global Reporting Iniciative (2015) G4 guidelines – reporting principles and standard disclosures. Avaliable in https://www.globalreporting.org/resourcelibrary/GRIG4-Part1-Reporting-Principles-and-Standard-Disclosures.pdf. Access in March 2016

Guthrie J, Petty R, Yongvanich K, Ricceri F (2004) Using content analysis as a research method to inquire into intellectual capital reporting. J Intellect Cap 5(2):282–293. https://doi.org/10.1108/14691930410533704

Hackston D, Milne MJ (1996) Some determinants of social and environmental disclosures in New Zealand companies. Account Audit Account J 9(1):77–108. https://doi.org/10.1108/09513579610109987

Hallenberg A (2015) Climate change and financial market efficiency. Business and Society 54:511–539

Halsnæs K, Garg A, Christensen J, Føyn HY, Karavai M, La Rovere E et al (2014) Climate change mitigation policy paradigms—national objectives and alignments. Mitig Adapt Strateg Glob Chang 19(1):45–71. https://doi.org/10.1007/s11027-012-9426-y

Haque S, Deegan C (2010) Corporate climate change-related governance practices and related disclosures: evidence from Australia. Aust Account Rev 55:317–333

Haque, S., Deegan, C., & Inglis, R. (2013) Disclosure of climate change-related corporate governance practices

Hurvich CM, Tsai CL (1995) Model selection for extended quasi-likelihood models in small samples. Biometrics 51(3):1077–1084

Corporate Library Inc. (2009) Climate risk disclosure in SEC filings: an analysis of 10-K reporting by oil and gas, insurance, coal, transportation and electric power companies. Environmental Defense Fund

IPCC Climate Change (2007) The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC, Cambridge University Press, Cambridge, UK/New York, USA

IPCC. Climate Change 2014 Mitigation of Climate Change Available in Https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_full.pdf Accessed on 23 Feb. 2016

Jennifer Ho LC, Taylor ME (2007) An empirical analysis of triple bottom line reporting and its determinants: evidence from the United States and Japan. Journal of International Financial Management & Accounting 18(2):123–150. https://doi.org/10.1111/j.1467-646X.2007.01010.x

Jensen MC (1993) The modern industrial revolution, exit, and the failure of internal control systems. J Financ 48(3):831–880. https://doi.org/10.1111/j.1540-6261.1993.tb04022.x

Jensen MC, Meckling WH (1976) Theory of the firm: managerial behavior, agency costs and ownership structure. J Financ Econ 3(4):305–360. https://doi.org/10.1016/0304-405X(76)90026-X

Kennedy I, García Sánchez IM, Silva Vieira C (2014) Climate change and financial performance in times of crisis. Bus Strateg Environ 23(6):361–374

Kolk A, Walhain S, Van de Wateringen S (2001) Environmental reporting by the Fortune Global 250: exploring the influence of nationality and sector. Bus Strateg Environ 10(1):15–28. https://doi.org/10.1002/1099-0836(200101/02)10:1<15::AID-BSE275>3.0.CO;2-Y

Kouloukoui, D. (2016). O disclosure de informações de riscos climáticos e o retorno anormal do preço das ações das empresas brasileiras. Dissertation. Federal University of Bahia. http://repositorio.ufba.br/ri/handle/ri/20060

Labatt S, White RR (2007) Carbon finance. John Wiley and Sons

Lang M, Lundholm R (1993) Cross-sectional determinants of analyst ratings of corporate disclosures. J Account Res 31(2):246–271. https://doi.org/10.2307/2491273

Lee SY (2012) Corporate carbon strategies in responding to climate change. Bus Strateg Environ 21(1):33–48. https://doi.org/10.1002/bse.711

Lee T, Hughes S (2017) Perceptions of urban climate hazards and their effects on adaptation agendas. Mitig Adapt Strateg Glob Chang 22(5):761–776. https://doi.org/10.1007/s11027-015-9697-1

Su–Tome Lee, Park, Yun-Seon, Klassen, Robert D (2015) Market responses to firms' voluntary climate change information disclosure and carbon communication. Corporate Social Responsibility and Environmental Management, v. 22, n. 1–12

Leftwich RW, Watts RL, Zimmerman JL (1981) Voluntary corporate disclosure: the case of interim reporting. J Account Res 19:50–77. https://doi.org/10.2307/2490984

Leurig S (2011) Climate risk disclosure by insurers: evaluating insurer responses to the NAIC climate disclosure survey. N Y 54

Leurig S, Dlugolecki CDA (2013) Insurer climate risk disclosure survey. Ceres, Boston

Li W, Jia Z (2017) Carbon tax, emission trading, or the mixed policy: which is the most effective strategy for climate change mitigation in China? Mitig Adapt Strateg Glob Chang 22(6):973–992. https://doi.org/10.1007/s11027-016-9710-3

Lindblom, C. K. (1994). The implications of organizational legitimacy for corporate social performance and disclosure. In: Paper presented at the *Critical Perspectives on Accounting Conference*, pp. 1e26. *New York* (Vol. 120)

Linnerooth-Bayer J, Hochrainer-Stigler S (2015) Financial instruments for disaster risk management and climate change adaptation. Clim Chang 133(1):85–100. https://doi.org/10.1007/s10584-013-1035-6

Lipton, M., & Balatonalmadi, J. W. (1992) A modest proposal for improved corporate governance. *The business lawyer*, 59-77

Lodhia S (2005) Legitimacy reasons is world wide web (www) environmental reporting: an exploratory study into present practices in the Australian minerals industry. Journal of Accounting and Finance 4:1e15

McNichols M, Manegold JG (1983) The effect of the information environment on the relationship between financial disclosure and security price variability. J Account Econ 5:49–74. https://doi.org/10.1016/0165-4101(83)90005-8

McCullagh, P. (1984). Generalized linear models. European Journal of Operational Research, 16(3):285–292.

Mills E (2007) Synergisms between climate change mitigation and adaptation: an insurance perspective. Mitig Adapt Strateg Glob Chang 12(5):809–842. https://doi.org/10.1007/s11027-007-9101-x

Nasi J, Nasi S, Phillips N (1997) The evolution of corporate social responsiveness. Business and Society 36(3): 296e321

Nazli Nik Ahmad N, Sulaiman M (2004) Environment disclosure in Malaysia annual reports: a legitimacy theory perspective. Int J Commer Manag 14(1):44–58. https://doi.org/10.1108/10569210480000173

Nelder JA, Wedderburn RWM (1972) Generalized linear models. J R Stat Soc 135(2):370–384. https://doi.org/10.2307/2344614

Newson M, Deegan C (2002) Global expectations and their association with corporate social disclosure practices in Australia, Singapore, and South Korea. The International J Account Econ 37:183–213

Nikolaou I, Evangelinos K, Leal Filho W (2015) A system dynamic approach for exploring the effects of climate change risks on firms' economic performance. J Clean Prod 103:499–506. https://doi.org/10.1016/j.jclepro.2014.09.086

O'Donovan, G., (1999a) Corporate legitimacy and environmental reporting: identifying the audiences and choosing disclosure approaches. Interdisciplinary Environmental Review, and An Anthology 1 (2), 83e106

O'Donovan G (1999b) Managing legitimacy through increased corporate environmental reporting: an exploratory study. Interdiscip Environ Rev 1(1):63e99

O'Donovan G (2002a) Environmental disclosure in the annual report: extending the applicability and predictive power of legitimacy theory. Accounting, Auditing and Accountability Journal 15(3): 344e371

O'Donovan, G. (2002b). Corporate environmental reporting: developing the legitimacy theory model. In: 2002 AAANZ Conference. Victoria University, School of Accounting and Finance, pp. 1e33

Patten D (1991) Exposure, legitimacy and social disclosure. J Account Public Policy 10(4):297e308

Patten DM (1992) Intra-industry environmental disclosures in response to the Alaskan oil spill: a note on legitimacy theory. Acc Organ Soc 17(5):471–475. https://doi.org/10.1016/0361-3682(92)90042-Q

Patten DM, Trompeter G (2003) Corporate responses to political costs: an examination of the relation between environmental disclosure and earnings management. J Account Public Policy 22(1):83–94. https://doi.org/10.1016/S0278-4254(02)00087-X

Pauw WP, Klein RJ, Vellinga P, Biermann F (2016) Private finance for adaptation: do private realities meet public ambitions? Clim Chang 134(4):489–503. https://doi.org/10.1007/s10584-015-1539-3

Pellegrino C, Lodhia S (2012) Climate change accounting and the Australian mining industry: exploring the links between corporate disclosure and the generation of legitimacy. J Clean Prod 36:68–82. https://doi.org/10.1016/j.jclepro.2012.02.022

Perry M, Tse Sheng T (1999) An overview of trends related to environmental reporting in Singapore. Environ Manag Health 10(5):310–320. https://doi.org/10.1108/09566169910289667

Pfeifer S, Sullivan R (2008) Public policy, institutional investors and climate change: a UK case-study. Clim Chang 89(3):245–262. https://doi.org/10.1007/s10584-007-9380-y

Pinkse J, Kolk A (2009) International business and global climate change. Routledge, London

Pwc - Pricewaterhouse Coopers (2015) Global Top 100 Companies by market capitalization - PwC. Available in: https://www.pwc.com/gx/en/audit-services/publications/assets/global-top-100-companies-2016.pdf. Access in March 2016

Reid EM, Toffel MW (2009) Responding to public and private politics: corporate disclosure of climate change strategies. Strateg Manag J 30(11):1157–1178. https://doi.org/10.1002/smj.796

Riani, M., & Atkinson, A. C. (2000). Robust diagnostic data analysis: transformations in regression. Technometrics, 42(4):384–394.
Roberts RW (1992) Determinants of corporate social responsibility disclosure: an application of stakeholder theory. Acc Organ Soc 17(6):595–612. https://doi.org/10.1016/0361-3682(92)90015-K
Rodrigue M, Magnan M, Cho CH (2013) Is environmental governance substantive or symbolic? An empirical investigation. J Bus Ethics 114(1):107–129. https://doi.org/10.1007/s10551-012-1331-5
Rohat G, Goyette S, Flacke J (2017) Twin climate cities—an exploratory study of their potential use for awareness-raising and urban adaptation. Mitig Adapt Strateg Glob Chang 22(6):929–945. https://doi.org/10.1007/s11027-016-9708-x
Sant'Anna ÂMO (2015) Framework of decision in data modeling for quality improvement. The TQM Journal 27(1):135–149. https://doi.org/10.1108/TQM-06-2013-0066
Smith JA, Morreale M, Mariani ME (2008) Climate change disclosure: moving towards a brave new world. Capital markets law journal 3(4):469–485. https://doi.org/10.1093/cmlj/kmn021
Stanny E, Ely K (2008) Corporate environmental disclosures about the effects of climate change. Corp Soc Responsib Environ Manag 15(6):338–348. https://doi.org/10.1002/csr.175
Stanwick SD, Stanwick PA (2000) The relationship between environmental disclosures and financial performance: an empirical study of US firms. Eco-Mgmt. Aud. 7(4):155–164. https://doi.org/10.1002/1099-0925(200012)7:4<155::AID-EMA137>3.0.CO;2-6
Stray S, Ballantine J (2000) A sectoral comparison of corporate environmental reporting and disclosure. Eco-Mgmt Aud 7(4):165–177. https://doi.org/10.1002/1099-0925(200012)7:4<165::AID-EMA138>3.0.CO;2-2
Suchman, M. C. (1995) Managing legitimacy: strategic and institutional approaches. *Academy of Management Review*, *20*(3), 20:3 571-610. doi:https://doi.org/10.5465/AMR.1995.9508080331
Suttipun M, Stanton P (2012a) Determinants of environmental disclosure in Thai corporate annual reports. International Journal of Accounting and Financial Reporting 2(1):99. https://doi.org/10.5296/ijafr.v2i1.1458
Suttipun M, Stanton P (2012b) The differences in corporate environmental disclosures on websites and in annual reports: a case study of companies listed in Thailand. International Journal of Business and Management 7(14):18
Williams SM (1999a) Voluntary environmental and social accounting disclosure practice in the Asia-Pacific region: an empirical test of political economy theory. The International J Account Econ 34(2):209–238
Wittneben BB, Kiyar D (2009) Climate change basics for managers. Manag Decis 47(7):1122–1132. https://doi.org/10.1108/00251740910978331
Zeghal D, Ahmed SA (1990) Comparison of social responsibility information disclosure media used by Canadian firms. Account Audit Account J 3(1). https://doi.org/10.1108/09513579010136343
Ziegler A, Busch T, Hoffmann VH (2011) Disclosed corporate responses to climate change and stock performance: an empirical analysis. Energy Econ 33(6):1283–1294. https://doi.org/10.1016/j.eneco.2011.03.007