Indian Growth and Development Review

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Unveiling the nexus between board quality, firm innovation and climate risk disclosure: a study of Indian companies

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Received 23 May 2024
Revised 12 October 2024
3 January 2025
Accepted 11 January 2025

Abstract

Purpose – This study aims to explore the association of board quality and firm innovation on climate risk disclosure in the context of large listed companies in India. It builds upon the framework developed by the stakeholder theory and the legitimacy theory to examine the association between the key variables of the study.

Design/methodology/approach – The climate risk disclosure is measured through content analysis of the annual reports of the respective companies. A panel data framework analyzes the relationship between board quality, firm innovation and climate risk disclosure.

Findings – The findings indicate a gradual increase in climate risk disclosure throughout the sample period. This study also finds that certain board characteristics and investment in innovation are significant determinants of a firm's approach toward identifying and mitigating risks arising from rapid climate change. This study has implications for practitioners, policymakers and academicians who strive toward creating resilient and sustainable organizations.

Research limitations/implications – This study is relevant for practitioners as it identifies an increasing trend in the identification and reporting of climate risk disclosure in the sample firms. This would be beneficial for managers and other stakeholders of the organizations who would be interested in the mitigation of climate risk. The organizational leadership may identify key parameters of their firms, which helps them prepare against the adverse impact of climate change on business.

Originality/value – To the best of the authors' knowledge, this is the first study to evaluate climate risk disclosure practices of large listed companies in India. This study highlights how large Indian companies are developing an overall approach for identifying and mitigating risks associated with rapid climate change, which has not been conducted for any economy.

Keywords Climate risk disclosure, Innovation, Board size, Gender diversity, Board diligence

Paper type Research paper

1. Introduction

In the contemporary business landscape, organizations increasingly acknowledge climate risk's influence on their long-term performance. Organizations need to develop strategies to identify and mitigate climate risk for sustainable growth. Such an approach motivates them toward a comprehensive disclosure of various kinds of risks including those arising because of rapid climate change. The perception of various stakeholders has also evolved because of

Indian Growth and Development Review
Vol. 18 No. 1, 2025
pp. 93-111

1753-8254
DOI 10.1108/IGDR-05-2024-0071

organizations' vulnerability toward climate change which demands holistic disclosure in this regard. Climate risk disclosure is a crucial tool for building confidence among stakeholders by offering transparency about the firms' strategy toward addressing such risks and positioning themselves for resilience amid a changing climate. Governments are in the process of implementing or contemplating regulations that mandate companies to disclose their climate-related strategies. Compliance with these regulations ensures legal adherence and reflects a commitment to responsible and sustainable business practices.

Climate risk disclosure enables companies to align with stakeholder expectations, showcasing dedication to sustainability and transparency. Proactively disclosing climate-related risks and strategies provides companies with a competitive advantage and attracts environmentally conscious investors, customers and partners. It elevates a company's reputation and refines its market positioning. Climate risk disclosure acts as a catalyst, compelling companies to incorporate climate considerations into their long-term strategic planning. This integration fosters improved decision-making and enhanced adaptability to navigate the dynamic landscape of a changing business environment.

At a global level, initiatives such as the Task Force on Climate-related Financial Disclosures (TCFD) underscore the international community's commitment to addressing climate change. These initiatives emphasize the collective responsibility of organizations worldwide to promote transparency and proactive measures to mitigate the impacts of climate change.

In recent years, corporate governance and board quality have gained significant attention from scholars and practitioners because of their potential impacts on firm performance, innovation and environmental disclosure. Corporate governance practices and board characteristics play a crucial role in shaping a company's approach to climate risk disclosure and environmental innovation. Research has shown that the composition of a company's board, including factors such as board size, independence and diversity, can influence the likelihood of publishing sustainability reports and comprehensive climate-risk disclosures.

As corporate governance continues to evolve, understanding the interplay among board quality, innovation and climate risk disclosure in Indian companies has become increasingly relevant. Recently in January 2024, the Reserve Bank of India (RBI) issued draft guidelines on the "Disclosure framework on climate-related financial risks" [1]. This framework mandates the disclosure of information on climate-related financial risks and opportunities for specific categories of banks and non-banking financial companies in India. Earlier Securities Exchange Board of India (SEBI) had also introduced a framework in 2021 on the Business Responsibility and Sustainability Reporting guidelines under the Listing Obligations and Disclosure Requirement (Shekhar and Chadda, 2024). The SEBI framework aims to enhance corporate transparency and accountability regarding sustainability practices including climate risk disclosure.

This study explores the relationship between board characteristics, innovation and climate risk disclosure in the context of Indian companies, providing valuable insights for policymakers, investors and corporate leaders. Given the growing interest in climate change disclosure and corporate governance in India, this study builds on the existing research to investigate the specific factors that influence climate risk.

Research has also identified the importance of investments in innovation in developing mitigation strategies toward climate risk and sustainable development. Organizations that are leaders in sustainable growth make investments toward innovation. These innovations can be in diverse forms like products, technology and processes. Investments in such innovation make the organization future-ready.

In light of the above considerations, the present study has the following objectives.

- RO1: Explore the level of climate risk disclosure among large listed companies in India.
- RO2: Evaluate board quality's impact on climate risk disclosure.
- RO3: Assess the impact of firm innovation on Climate Risk Disclosure.

This study aims to measure the level of climate risk disclosure of Indian companies it also seeks to contribute to the understanding of how Board Quality and firm innovation influence the disclosure of climate-related risks, recognizing the pivotal role that disclosure plays in managing risks, building trust, meeting regulatory standards and positioning businesses for long-term sustainability amid the escalating challenges associated with climate change. This study makes the following contributions. It is the first study that measures the climate risk disclosure of Indian companies through content analysis. The study also identifies specific board characteristics that may impact climate risk disclosure. To the best of our knowledge, this is the first study to explore the association between firm innovation and climate risk disclosure. It has implications for practitioners, policymakers and academicians in formulating a framework capable of making future-ready organizations that can handle newer risks that arise because of rapid climate change. The rest of the article is organized as follows. Section 2 presents a review of the related literature. Section 3 discusses sample selection and research methodology. Section 4 presents the results and discussions of the analysis; Section 5 presents the managerial implications of the study; and Section 6 concludes.

2. Literature review

The relationship between innovativeness and climate risk disclosure is multifaceted. Innovations can manifest in various aspects of a company's operations, from technological solutions to sustainable product offerings. These innovations are often reflected in how a company communicates its approach to climate-related risks. Disclosures serve as valuable tools for stakeholders to understand the depth of a company's commitment to innovation in the context of environmental sustainability. Various studies have been conducted on environmental disclosure and board quality. For instance, the study conducted by Pletsch *et al.* (2020) found a significant impact of board size on risk disclosure. The larger the board of directors, the better the quality of risk disclosure in companies in the noncyclical consumer sector.

In another study by Amran *et al.* (2014), women on board committees increased the likelihood of voluntary climate change disclosure, while overall women's representation on boards showed no positive impact on climate change reporting. Ararat and Sayedy (2019) also revealed that women on board committees increase the likelihood of voluntary climate change disclosure, while overall, women's representation on boards shows no positive impact on climate change reporting.

The study conducted by Ararat and Sayedy (2019) found that increasing independent non-executives on boards, separating Chief Executive Officer (CEO)-board chair roles and maintaining environmental certification can directly increase climate change disclosure in sustainability reports. The study conducted by Mbithi *et al.* (2022) also inferred that board independence and gender diversity positively influence the quality of risk disclosure in Kenyan listed firms, whereas firm size and leverage also positively influence it. Tila and Augustine (2019) found that corporate governance characteristics, such as diversity, independence and sustainability committees, positively influence carbon emissions disclosure, while carbon risk management positively impacts it.

2.1 Research in Indian context

The issue of climate change disclosure has gained increasing prominence in corporate governance, particularly as businesses are expected to align with global environmental standards. In the Indian context, the regulatory landscape and disclosure practices are evolving, particularly within high-impact sectors like energy. In the Indian context, various Indian authors have examined the state of corporate climate disclosure, revealing progress and gaps in this domain.

Singh and Joshi (2009) highlighted the growing importance of environmental management and disclosure practices among Indian corporations, stressing the need for better transparency in alignment with international reporting standards. Their study explores how Indian companies, particularly those in environmentally impactful sectors, are adapting to global norms, yet they note that further improvements are needed. They identify a correlation between environmental disclosures and certain corporate attributes, suggesting that stronger corporate governance is tied to better environmental transparency (Singh and Joshi, 2009).

Similarly, Maji and Kalita (2022) focus on the energy sector and investigate how climate change-related disclosures, particularly following the TCFD guidelines, influence firm performance. They find that Indian firms exhibit moderate disclosure levels, and better climate disclosures positively impact financial performance. This demonstrates that transparency around climate issues is not only beneficial for environmental governance but can also drive better financial outcomes (Maji and Kalita, 2022).

Bhaduri (2021) compared climate risk disclosure practices in India with those in the USA, noting the rise of climate-related securities litigation in the latter. In India, while regulatory bodies such as the SEBI mandate the disclosure of material risks, including those related to climate change, enforcement remains weak. Bhaduri argues that the absence of comprehensive climate disclosure legislation creates a potential threat to financial markets, which could be mitigated by stronger regulatory frameworks (Bhaduri, 2021).

Building on this, Charumathi (2022) analyzed climate disclosures before and after the introduction of Business Responsibility Reporting and the Paris Climate Accord. They observed significant improvements in disclosures among large Indian firms, particularly in polluting industries. Their findings suggest that international agreements and domestic regulatory measures have driven positive changes in corporate behavior, yet there remains scope for further alignment with global standards (Charumathi, 2022).

In addition, Shekhar and Chadda (2024) propose a new regime for climate-related disclosures, addressing both the regulatory gaps and the need for greater corporate accountability. Their framework emphasizes comprehensive reporting and the integration of climate-related financial risks, especially for industries with significant environmental footprints. They also highlight the importance of climate disclosure for mitigating risks and improving corporate governance (Shekhar and Chadda, 2024).

Other researchers, such as Mishra and Sant (2024), extend this examination to the banking sector, noting a growing emphasis on environmental, social and governance (ESG) disclosures in sustainability reports. Their study shows that although Indian banks are increasingly incorporating ESG factors, there is still substantial variability in the quality and scope of disclosures, particularly regarding environmental risks (Mishra and Sant, 2024).

Similarly, Vaze *et al.* (2022) discussed the broader implications of climate-related financial risks for India's regulatory bodies, such as the RBI. They argue that effective climate-related risk disclosure is essential for managing the financial system's exposure to environmental risks, proposing a range of policy options to enhance the RBI's role in overseeing these disclosures (Vaze *et al.*, 2022).

In a similar stream of research, Bedi and Singh (2024) developed a comprehensive carbon disclosure index and examined the stakeholder pressure for disclosure. While the carbon disclosure index primarily focuses on the extent of carbon emissions of the sample firms, climate risk disclosure has a broader scope for consideration.

Collectively, these studies indicate that while Indian companies are gradually improving their climate-related disclosures, more comprehensive and consistent reporting is necessary to meet global standards. Enhanced transparency will not only mitigate climate risks but also optimize firm performance and strengthen investor confidence.

2.1.1 Research framework and hypothesis testing. This article explores the association between board characteristics, firm innovation and climate risk disclosure among large listed companies in India. This relationship may be explained by two prevalent theories in management literature: the stakeholder theory and the legitimacy theory. According to the stakeholder theory, the board of directors value the interests of all stakeholders while making key organizational decisions (Jensen, 1993; Lu and Abeysekera, 2017). In doing so, they would also want to present an environmentally responsible image. The organizations having quality boards should also witness superior climate risk disclosure keeping in consideration the interests of all stakeholders while managing their impressions about its functioning. The stakeholder theory can also be used to understand the relationship between firm innovation and its climate risk disclosure (Coluccia *et al.*, 2020). This theory highlights the long-term objectives of the firm to meet the interests of all stakeholders. Therefore, responsible organizations would be adopting policies fostering innovation and would also be motivated toward a holistic approach in identifying and mitigating climate risk.

Another theory that supports the disclosure of climate risk is the legitimacy theory. This theory assumes a bond between the organization and the society in which it operates. This bond develops because of the shared values, culture and belief system (Lindblom, 1994; Stanny and Ely, 2008). The organizations are expected to operate as per the expectations of the society. The organization's right to continue its operations may be revoked by society if it is found to be violating the expectations of society. When the existence and growth of the organization depend on its functioning as per society's expectations, it is expected that the organization will try to pursue those activities which will prove its legitimacy. Such organizations would have superior quality boards and might be motivated toward increased disclosure in terms of their vulnerability toward climate risk and its mitigation strategies adopted.

2.1.1.1 Board size and climate risk disclosure. The study of the relationship between board size and climate risk disclosure focuses on how a company's board of directors' constitution may affect the quantity and caliber of disclosure on climate risk. Board size can influence decision-making dynamics. A larger board may engage in more extensive discussions and deliberations, which could result in a more thorough examination of climate-related risks and their subsequent disclosure to stakeholders. The study conducted by Kouloukoui *et al.* (2018) revealed that Brazilian companies with larger boards and independent directors show better climate change management, suggesting that increasing independent directors on the board can improve climate change involvement. Moumen *et al.* (2016) found that board composition and size enhance the informativeness of risk disclosure, allowing investors to better predict future earnings growth, whereas CEO/chairperson duality does not impact trust in risk disclosures. However, contradictorily, the study conducted by Taurus (2020) revealed that larger board sizes negatively impact environmental accounting disclosure, while firm size positively impacts it, suggesting that firms should decrease board size and improve assets to increase environmental disclosure in Kenyan firms. Another study

advocated that companies' climate risk disclosure levels are influenced by their activity sector, continent and board efficiency, not their size or developed-country origin.

The study conducted by Ben-Amar *et al.* (2017) found that board effectiveness positively correlates with a firm's decision to respond to the Carbon Disclosure Project questionnaire and the quality of its carbon disclosures.

In light of the above, it is interesting to examine the relationship between Board Size and Climate Risk disclosure by Indian Companies. Therefore, the following hypothesis was formulated:

H1. Board Size is positively associated with Climate Risk Disclosure by Indian Companies.

2.1.1.2 Board independence and climate risk disclosure. The genuine governance efficacy of independent directors is contingent upon striking a balance between independence and the ability to acquire essential information. Achieving this equilibrium is essential to maximize the positive impact of an independent director system on corporate governance.

The independent director system functions as a pivotal mechanism in addressing the inherent agency problem within enterprises and alleviating associated risks, thereby playing a crucial role in protecting investor wealth and ensuring the stability of the capital market. Studies have shed light on various factors that influence firms' risk mitigation, including the external institutional environment (Wang *et al.*, 2021; Johnson *et al.*, 2010; Hilary and Hui, 2009), corporate governance mechanisms (Cole, 2008; Faccio *et al.*, 2011; Kini and Williams, 2012) and manager characteristics (Faccio *et al.*, 2011; Alqatamin *et al.*, 2017; Kong *et al.*, 2020; Serfling, 2014).

The independent director system, as emphasized by the seminal work of Fama and Jensen (1983), addresses the agency problem within enterprises and mitigates the associated risks. The effectiveness of independent directors in fulfilling their governance role is contingent on their access to firm-specific information (Adams and Ferreira, 2007). However, a notable challenge arises, as the information upon which independent directors rely on decision-making often comes from managers, who may be inclined to withhold crucial information to protect the private benefits of management. In situations where such information concealment occurs, the governance impact of independent directors is compromised (Adams and Ferreira, 2007).

Therefore, it is worthwhile to analyze the impact of director attendance on climate risk disclosure. Considering the above, the second hypothesis of the study is formulated as follows:

H2. Board independence is positively associated with climate risk disclosure by Indian Companies

2.1.1.3 Board gender diversity and climate risk disclosure. The present study attempts to examine the relationship between gender diversity on corporate boards and climate risk disclosure as an emerging area of research that explores how gender diversity may impact a company's approach to disclosing information about climate-related risks. Gender diversity brings a variety of perspectives to the boardroom. Female directors may bring unique insights into sustainability, social responsibility and community impacts, influencing the board's discussions and decisions related to climate risk.

Various studies (e.g. Ararat and Sayedy, 2019; Omar and Amran, 2018; Hossain *et al.*, 2017; Ben-Amar *et al.*, 2017) suggest that gender diversity on corporate boards positively

impact carbon disclosure information, suggesting that companies with more female directors may achieve higher voluntary disclosure and promote corporate governance.

In light of the above, the following hypothesis was formulated:

H3. Gender Diversity is positively associated with Climate Risk Disclosure among Indian Companies.

2.1.1.4 d. Board diligence and climate risk disclosure. Diligence in addressing climate risk disclosure requires a proactive and comprehensive approach, integrating climate considerations into the core of corporate governance and decision-making processes. Boards that prioritize sustainability and climate resilience are better positioned to navigate the challenges and opportunities presented by a changing climate. The diligence of a board of directors in addressing climate-related risks and disclosing relevant information is crucial in today's business landscape, where environmental issues can have significant financial and reputational impacts on companies.

Various studies were conducted to know the impact of board effectiveness on the firm disclosure. For instance, the study conducted by Ben-Amar *et al.* (2017) found that board effectiveness positively correlates with a firm's decision to respond to the Carbon Disclosure Project questionnaire and the quality of its carbon disclosures. Similarly, the study conducted by Allegrini and Greco (2013) concluded that diligent monitoring activity in corporate boards is associated with greater transparency to the outside and larger boards do not negatively impact voluntary disclosure for outside shareholders in an agency setting.

In light of the above, it is obvious to find out the relationship board diligence on the climate risk disclosure. Hence, the fourth hypothesis of the study is formulated as follows:

H4. Board's diligence is positively associated with climate risk disclosure among Indian Companies.

2.1.1.5 e. Firm innovation and climate risk disclosure. The relationship between innovation and climate risk disclosure is multifaceted, and innovative practices can enhance the effectiveness and transparency of a company's approach to disclosing climate-related risk. Innovation plays a crucial role in enhancing the capabilities of organizations to assess, monitor and disclose climate-related risks. As technology continues to advance, it is likely to further influence and improve the effectiveness of climate risk disclosure practices in various industries.

Numerous studies highlight the importance of investments in innovation in developing mitigation strategies toward climate risk and sustainable development (Wang *et al.*, 2021; Oliva *et al.*, 2022). Organizations that are leaders in sustainable growth make investments toward innovation. These innovations can be in diverse forms like products, technology and processes. Investments in such innovation make the organization future-ready. These organizations should also be motivated to disclose their approach toward climate risk identification and mitigation.

The present study tries to explore whether the companies spending on innovation has significantly disclosed the clime risk information or not. In light of this, the fifth hypothesis is formulated as follows:

H5. Firm Innovation is positively associated with climate risk disclosure among Indian Companies.

3. Sample selection and research methodology

We started the sample selection process with the largest 200 companies listed on the National Stock Exchange of India based on their market capitalization. These companies account for around 82% of the free float market capitalization of National Stock Exchange of India (NSE) as of December 2023. Banks and other financial institutions were excluded from the analysis because of their distinct regulatory and compliance framework. After removing companies with missing data, the final sample was 112 firms for 8 years (2014–2021) which comprised 896 firm-year observations. The time frame of the research is 2014–2021. The sample started from the year 2014 as the Companies Act was enacted in 2013. The nonfinancial/sustainability reporting came into center stage after this act along with the support of the SEBI 2012 regulations in this context.

The financial and governance data for the analysis was obtained from the Prowess database created by the Centre for Monitoring the Indian Economy. This database has been extensively used for corporate data in the Indian context. To obtain data on the disclosure quality, annual reports of the respective firms were downloaded from their respective websites. The annual reports were analyzed to measure the level of climate risk disclosure by the sample firms.

3.1 Calculation of climate risk disclosure

The present study evaluates the impact of firms' board quality and innovation on climate risk disclosure. To Explore the level of climate risk disclosure among large listed companies in India, the content analysis technique was applied to the annual reports of the sample firm yielding information related to mitigation and adaptation to climate risks by those organizations. The measure of the climate risk disclosure was the frequency count of all the climate disclosure-related keywords in the annual report of a firm in a given year. It is crucial to emphasize that, content analysis considers and quantifies information on climate risk disclosure only when discussed in the context of the parameters, namely, the climate risks facing the company (such as physical and regulatory risks); actions taken for mitigation, adaptation or expression of concerns and policies; and measures related to climate change, especially about climate risks and events related to global warming.

We followed the approach adopted by Kouloukoui *et al.* (2018) for content analysis of annual reports. A conceptual framework for the content analysis from the works of Haque and Deegan (2010), Intergovernmental Panel on Climate Change (IPCC, 2007; IPCC, 2014) and GRI (2013) was used to organize the sentences for extracting information on climate risks within the annual reports. The query run for assessing the frequency count of the climate disclosure-related keywords in the annual reports was generated as:

> "Climate risk," "Physical risk,"" Regulatory risk," "Competitive risk," "Legal risk," "Reputation risk," "Climate management," "Floods," "Natural disasters," "Storm" "Global warming," "Emissions," "CO_2," "Carbon footprint," "GHG protocol," "Environment Pollution," "Greenhouse gas" and "Climate change."

Although earlier studies have developed a comprehensive carbon disclosure index (Bedi and Singh, 2024), this study follows the conceptual framework for the content analysis from the works of Haque and Deegan (2010). This is because of the difference in the scope of climate risk disclosure and carbon disclosure. While the cardon disclosure primarily focuses on extent of carbon emissions of the sample firms, climate risk disclosure has a broader scope evaluating the overall impact of climate change on the company including climate risk, regulatory risk and carbon footprint of the firms under consideration.

3.2 Regression models

This study is based on a panel data framework to assess the impact of board quality and firm innovation on climate risk disclosure. Panel data indicates that firms are heterogeneous and allow to control for individual heterogeneity. Also, panel data provide more informative data, increased variability, higher degrees of freedom and less collinearity among variables and thus, increase the efficiency of the model (Baltagi and Baltagi, 2008). The two common techniques to model panel data are the fixed effect model (FEM) and the random effect model (REM) for regression. Both these models differ in the assumptions about the correlation between the unobserved effect of the panel data and the explanatory variables of the model. The formal test to determine the suitability of the regression techniques is the Hausman specification Test (Hausman, 1978).

The primary objective of the study is to evaluate the association between board quality and firm innovation with climate risk disclosure. Therefore, board quality is proxied by the following four variables: board size, board independence, board gender diversity and board diligence and firm innovation is proxied by the total research and development expenditure of the firm in a given year. Some other variables were also included in the analysis to control for their probable impact on climate risk disclosure. Therefore, the following model is proposed:

$$DIS_{it} = \beta_0 + \beta_1 * BS_{it} + \beta_2 * BI_{it} + \beta_3 * GD_{it} + \beta_4 * BD_{it} + \beta_5 * INN_{it} + \beta_6 * SIZE_{it} + \beta_7 * LEV_{it} + \beta_8 * ROA_{it} + \beta_9 * II_{it} + \beta_{10} * Stock_{it} + \varepsilon_{it} \quad (1)$$

where BS, BI, GD, BD and INN are the main exploratory variables of the analysis. The list of the variables and their measurement are presented in Appendix 1 Table A1. Some control variables were also included in the analysis because of their probable association with climate risk disclosure. Several studies have found company size to be associated with climate risk environmental and climate risk disclosure (Hackston and Milne, 1996; Prado-Lorenzo *et al.*, 2009; Stanny and Ely, 2008; Kouloukoui *et al.*, 2019). Larger organizations are more "visible" in terms of their activities and bear a relatively larger burden of social expectations. They also have a larger number of stakeholders than their peers. Thus, company size might impact climate risk disclosure in the Indian context as well. Similarly, financial leverage has an association with climate risk disclosure. The firms with higher leverage aspire for creditor confidence and would try to meet their expectations (MurciaI *et al.*, 2014; Lu and Abeysekera, 2017; Kouloukoui *et al.*, 2019). Financial performance might also have an association with climate risk disclosure. Firms with superior financial performance seek to differentiate themselves and therefore, maintain higher levels of disclosure (Akerlof, 1970; Cohen and Kaimenakis, 2007; Kouloukoui *et al.*, 2019). Therefore, two distinct measures of financial performance, return on asset (ROA) and annual change in stock price were included as control variables in equation (1). The presence of institutional investors is also found to be associated with climate risk disclosure (Ilhan *et al.*, 2023). Institutional investors are one of the dominant stakeholders and demand complete and accurate disclosures including that of climate risk. Previous studies have documented an association between climate risk disclosure (Gerged *et al.*, 2021; Ilhan *et al.*, 2023).

4. Results and discussions

This study explores the level of climate risk disclosure among large listed companies in India. Table 1 presents the year-wise variation in climate risk disclosure. The mean value for the measure of climate risk disclosure is 622.2. This indicates that the sample firms are

Table 1. Year-wise disclosure of climate risk disclosure

Year	Mean	Min.	Max.
2014	334.2	1	1,349
2015	388.4	95	1,603
2016	433.8	69	1,794
2017	625.7	43	2,008
2018	661.1	91	1,945
2019	757.8	64	2,308
2020	848.0	22	2,646
2021	929.1	301	2,753
Overall	622.2	1	2,753

Source: Authors' own work

conscious of the impact of climate risk and are gearing up for its identification and mitigation. The minimum and maximum values for this variable over the entire sample period are 1 and 2,753, respectively, which highlights that there is a large variation among the firms in terms of their sensitivity toward climate risk. It is evident from Table 1 that there is a consistent increase in this variable. Thus, it can be concluded that the large listed Indian companies are adequately disclosing climate risk.

As the regulatory and (nonfinancial) reporting framework became increasingly stringent and comprehensive in India as well as globally, the same was reflected in the annual reports of the firms. It can also be argued that with the increased levels of awareness about the incidental climate risks and its inevitable impact on all walks of life including business, the companies in India started including these dimensions in their strategic management processes. They began to explore the organizations' vulnerability toward climate risk and approaches to mitigate such exposure. Similar findings have been reported by studies conducted in other contexts as well (Kouloukoui *et al.*, 2019; Ilhan *et al.*, 2023).

Table 2 presents the descriptive statistics of the variables. The variable board size has a mean of 11.33 with a standard deviation of 3.205. It ranges from a minimum of 4 directors on the board to a maximum of 24 directors. The variable of board independence has a mean of 51% with a minimum (maximum) of 0% (91.6%). This indicates that almost half of the board

Table 2. Descriptive statistics

	Mean	Std. dev.	Min.	Max.
DIS	622.2	388.4	1	2,753
BS	11.33	3.205	4	24
BI	0.511	0.120	0	0.916
GD	0.130	0.076	0	0.50
BD	5.175	1.777	1.7	17.06
INN	0.713	1.505	0	16.10
SIZE	5.114	0.604	3.63	6.987
LEV	0.180	0.265	0.001	5.282
ROA	0.086	0.161	−2.79	0.830
II	29.89	13.41	0.01	79.33
Stock	27.95	106.5	−94	2,507

Source: Authors' own work

directors in the sample are independent. The variable of board gender diversity has a mean of 13% with a maximum of 50%. This suggests that although there is women's participation in corporate boards in India, this proportion needs improvement. Similarly, the variable of board diligence has a mean of 5.175 with a range of 1.7–17.06. All these measures of board quality can be compared with similar studies (Kapoor and Goel, 2019; Chatterjee, 2020). The variable measuring firm innovation has a mean of 0.713 which varies between 0 and 16.10. The measure of firm innovation follows previous studies in the Indian context (Godil *et al.*, 2021; Krishnan, 2017).

Table 3 presents the cross-correlation between the important variables of the study. All of the independent variables do not exhibit a strong correlation with any other variable. The coefficient of correlation for climate risk disclosure and firm size is 0.57. Similarly, the coefficient of correlation for leverage and ROA is −0.67. All other variables have low values for the coefficient of correlation.

The model evaluates the impact of board quality and innovation on climate risk disclosure. The two common techniques to analyze panel data models are the FEM and REM. The Hausman Specification test was conducted which confirmed the suitability of the FEM technique of regression for the analysis. This technique also controls for time-invariant endogeneity in the sample. To test for probable heteroscedasticity in the sample, the modified Wald test for groupwise heteroskedasticity was conducted. The results of the test are presented in Table 4. Because of the presence of heteroscedasticity as indicated by the test, the FEM model was adjusted through cluster-corrected standard errors.

Another common estimation technique that addresses the endogeneity issue is a dynamic panel regression model based on Arellano and Bond's dynamic generalized method of

Table 3. Cross-correlation

	DIS	BS	BI	GD	BD	INN	SIZE	LEV	ROA	II	Stock
DIS	1.00										
BS	0.23*	1.00									
BI	−0.01	−0.15*	1.00								
GD	0.24*	−0.20*	0.12*	1.00							
BD	0.32*	0.18*	−0.17*	−0.02	1.00						
INN	0.19*	0.10*	0.13*	0.06***	0.06**	1.00					
SIZE	0.57*	0.44*	−0.09*	0.03	0.36*	0.29*	1.00				
LEV	0.00	−0.06**	−0.10*	0.03	0.12*	−0.05***	0.09*	1.00			
ROA	−0.05	0.06**	0.03	−0.03	−0.00	−0.02	−0.07**	−0.67*	1.00		
II	0.33*	0.18*	0.17*	0.07**	0.16*	0.23*	0.22*	−0.19*	0.11*	1.00	
Stock	−0.01	−0.13*	−0.01	0.03	−0.02	−0.05***	−0.08**	0.14*	0.07**	−0.11*	1.00

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

Table 4. Diagnostic tests

	Modified Wald test	LM test for serial autocorrelation
Statistic	Chi2 (112) = 6,908.03	$F(1, 111) = 23.667$
Prob	0.00	0.00

Source: Authors' own work

moments (GMM). Such models are more suitable for long-term analysis and for capturing the dynamic behavior of economic relationships. However, these kinds of GMM estimators are valid only in the absence of serial correlation in the idiosyncratic errors (Ullah *et al.*, 2018). Therefore, a dynamic regression model estimation could not be adopted for this model. The model was also tested for serial autocorrelation using the LM test. The results of the test indicated the presence of serial autocorrelation. The results of the test are also presented in Table 4.

Another issue that might arise in such panel data analysis is the cross-section dependence (CSD) in the errors. This may occur when all units in the same cross-section are correlated in the panel (De Hoyos and Sarafidis, 2006). CSD arises because of the presence of common factors impacting all companies operating in an economic environment. Therefore, the model was tested for cross-section dependence following Pesaran *et al.* (2004) and Pesaran (2015), which is appropriate for $N > T$. The results of the test indicated the presence of cross-sectional dependence for the majority of the variables. The results of the test are presented in Table 5.

The sample in this study has a large number of cross-sections and a small time period. In such cases, cross-section dependence is mainly seen in a "weak" form. That means the coefficient estimates are asymptotically unbiased and dependence remains in the residuals. Therefore, a CSD robust variance estimator is required like the Driscoll–Kraay standard errors (DKSE) regression. Driscoll and Kraay's approach modifies the standard nonparametric time-series covariance matrix estimator to be robust to cross-sectional and temporal dependence (Hoechle, 2007). Driscoll-Kraay standard error regression estimates are robust to disturbances being heteroskedastic, autocorrelated and cross-sectionally dependent. Therefore, this technique was also used to test the model and the results are presented in Table 6.

Among the four board quality proxies, the coefficient of board size is positive and significant at a 5% level of significance in the DKSE model. The coefficient was also positive and significant at a 10% level of significance in the FEM. Thus, *H1* is supported. This indicates that a larger board is associated with better disclosures in terms of environmental risks. This finding supports similar studies (Moumen *et al.*, 2016; Kouloukoui *et al.*, 2018) which argue that larger boards bring more insights and decision-making dynamics necessary for climate risk disclosure. The coefficient of board independence as another measure of board quality is not significant statistically. Thus, *H2* is rejected. The next proxy for board

Table 5. Test for cross-section independence

	CD test	*p*-value
DIS	170.3	0.00
BS	3.41	0.00
BI	1.915	0.05
GD	75.07	0.00
BD	19.04	0.00
INN	1.47	0.14
SIZE	136.8	0.00
LEV	10.82	0.00
ROA	2.7	0.00
II	47.45	0.00
Stock	93.52	0.00

Source: Authors' own work

Table 6. Regression results

	FEM		REM		DKSE	
	Coefficient	*t*-stat	Coefficient	*z*-stat	Coefficient	*t*-stat
BS	8.085***	1.77	5.6185	1.36	8.372**	2.56
BI	−103.92	−0.99	−68.788	−0.72	−113.8	−0.96
GD	1571.8*	11.15	1685.0*	12.81	1583.5*	6.63
BD	12.281***	1.91	18.550*	3.01	12.081**	2.47
INN	0.0707**	2.51	0.02921	1.23	928.55***	2.23
SIZE	726.91*	12.17	389.44*	11.96	745.40*	16.03
LEV	35.813	0.64	−47.987	−0.89	40.866	0.70
ROA	−113.53	−1.35	−163.037**	−1.98	−109.63***	−1.90
II	6.9186*	4.22	6.8656*	5.75	7.0708*	3.95
Stock	0.2398*	3.08	0.2445*	3.09	0.2281	1.58
Cons	−3631.2*	−12.55	−1911.0*	−11.89	−3717.6*	−16.71
F-stat (prob)	61.93 (0.00)	236.51 (0.00)				
Chi^2 (prob)	613.06 (0.00)					
R^2	0.41	0.43	0.44			

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

quality is gender diversity. The coefficient of this variable is also positive and significant, at a 1% level of significance for all the models adopted for estimation indicating the importance of board independence for superior climate risk disclosure. Thus, *H3* is supported. This conforms to other studies which highlight the role of gender-diverse boards for superior climate risk disclosure (Ararat and Sayedy, 2019; Omar and Amran, 2018; Hossain *et al.*, 2017; Ben-Amar *et al.*, 2017). The coefficient of variable board diligence is also positive and significant at a 5% and 10% level of significance for DKSE and FEM models respectively. Thus, *H4* is supported. The finding indicates that a diligent board contributes to generating better climate risk disclosure. This follows previous studies that argue that board diligence is critical in organizational reporting including climate risk disclosure (Ben-Amar *et al.*, 2017; Allegrini and Greco, 2013; Kapoor and Goel, 2019).

The next variable of interest is firm innovation. The coefficient of this variable is also positive and significant at a 10% and 5% level of significance for DKSE and FEM models respectively. Thus, *H5* is supported. This suggests that innovative firms have a higher climate risk disclosure. This finding highlights the importance of investments in innovation to mitigate climate risk and sustainable development. It follows previous studies which argue for greater emphasis on firm innovation through investments in research and development (Wang *et al.*, 2021; Oliva *et al.*, 2022).

Few control variables were also included because of their probable association with climate risk disclosure. The coefficient of variable for firm size was positive and significant at a 1% level of significance. This follows other studies which found a relationship between the size of the firm and its climate risk disclosure (Hackston and Milne, 1996; Prado-Lorenzo *et al.*, 2009; Stanny and Ely, 2008; Kouloukoui *et al.*, 2019). The variable of leverage was not found to be statistically significant for the sample firm. However, the coefficient of variable ROA was negative and statistically significant at a 10% level of significance. The coefficient of variable measuring institutional ownership was positively associated with climate risk disclosure at a 1% level of significance. This conforms to previous studies which document an association between institutional ownership and climate risk disclosure (Ilhan *et al.*, 2023).

Similarly, the coefficient of the variable measuring a change in stock price was also significant at a 1% level of significance in the FEM model. This follows previous studies which argue that well-performing firms have a need to differentiate themselves and try to maintain higher levels of disclosures including those of climate risk (Cohen and Kaimenakis, 2007; Kouloukoui *et al.*, 2019).

5. Managerial implications

The present study finds a significant association between certain characteristics of board quality and climate risk disclosure. Climate risk is increasingly being recognized as a key factor in strategic decision-making. A quality board may be better positioned to integrate climate-related considerations into overall corporate strategy. This includes assessing how climate risks and opportunities align with the organization's long-term goals and adjusting strategies accordingly. Boards with diverse compositions may have the ability to engage with a broader range of stakeholders. This engagement is crucial for understanding the expectations of investors, customers and other stakeholders regarding climate risk disclosure.

Companies should consider their unique circumstances carefully and adapt their governance and disclosure practices accordingly. The positive association between board quality and climate risk disclosure suggests that organizations with superior boards may be more committed to long-term sustainability. This commitment can enhance an organization's reputation, attract socially responsible investors and contribute to its resilience in the face of climate-related challenges. Furthermore, boards, especially larger ones, are crucial in ensuring compliance with evolving regulatory requirements related to climate risk disclosure. A quality may have the capacity to stay abreast of changing regulations and adapt disclosure practices accordingly to comply with emerging standards. It may facilitate better access to training and education resources regarding climate-related issues. Board members with diverse backgrounds may bring different levels of understanding regarding climate risks, and organizations can invest in programs to ensure that all members are well-informed. This education can lead to more informed decision-making and improved disclosure practices.

Board characteristics of size, gender diversity and diligence were found to have a positive association with climate risk disclosure. The study also finds an association between firm innovation and climate risk disclosure. This has implications for organizations striving toward sustainability goals. Leaders of such organizations should ensure board quality to be identified as sustainable. These organizations should also focus on innovation to be prepared for future risks. The insights developed from this study would be valuable to all the stakeholders of sustainable organizations as their identification becomes simpler. Organizations that have quality boards and an inclination toward innovation are the ones that are better equipped to manage climate-related risks. This study is also significant to policymakers who want to create resilient firms and business environments. Corporations may be encouraged to maintain board quality specifically in terms of board size, gender diversity and diligence and focus on innovation so that they are better prepared for risks arising because of the rapidly changing climate.

6. Conclusion

This study provides a significant contribution to understanding the dynamics of climate risk disclosure among large listed companies in India, particularly emphasizing the role of board characteristics and firm innovation. The findings reveal that specific board attributes – such as size, independence, gender diversity and diligence – have a substantial impact on the level of climate risk disclosure. Similarly, firm innovation emerges as a critical factor in driving transparency and the integration of climate risk into corporate reporting. These insights

contribute to the growing body of literature on corporate governance and environmental responsibility. The study's findings reflect global trends, where regulatory pressures and increased stakeholder demand for transparency are pushing companies to incorporate climate risk into their strategic decision-making and disclosure practices. For regulators and corporate managers alike, this research offers actionable recommendations on how board composition and innovative practices can be leveraged to improve climate-related reporting. The study also opens up new avenues for further exploration. Future research could broaden the scope by including smaller firms, privately held companies and a wider range of industry sectors to develop a more comprehensive understanding of disclosure patterns. A longitudinal approach would offer deeper insights into how disclosure practices evolve in response to regulatory changes and external pressures. In addition, comparative studies across countries could shed light on the influence of governance structures and innovation capacities in varying regulatory environments. Finally, examining the impact of climate risk disclosure on firm performance, particularly in terms of financial outcomes, reputation and shareholder value, as well as its integration with broader ESG frameworks, could provide valuable directions for advancing the field.

Note

1. www.rbi.org.in/Scripts/bs_viewcontent.aspx?Id=4393

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Appendix

Table A1. Variable list

Variables	Definition
DIS	Climate risk disclosure measured by the content analysis of the annual reports
BS	Board size measured as the total number of independent directors on the board
BI	Board independence is measured as the proportion of independent directors on the board
GD	Gender diversity of the board measured as the proportion of women directors on the board
BD	Board diligence is measured as the percentage attendance of the board of directors in board meetings
INN	Innovation is measured as the percentage of R&D expenditure to total assets of the firm
SIZE	Firm size measured as the log of total assets
LEV	Financial leverage
ROA	Return on asset
II	Institutional ownership is measured as the percentage of shares held by institutional shareholders
Stock	Percentage change in the stock price

Source: Authors' own work

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