DOES MANDATORY CSR REPORTING HELP COMBAT CLIMATE RISK IN THE PRESENCE OF GREEN FINANCE AND GREEN INNOVATION?

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Abstract
This study examines the effect of mandatory Corporate Social Responsibility (CSR) reporting on the Climate Risk Index (CRI) of European countries, a measure of global warming (SDG-13), where CSR reporting is mandated for a subset of large firms from 2012 to 2022. The objective is to assess the role of mandatory CSR reporting to combat the climate risk by aligning the sustainable corporate strategies with SDG-13. Employing the ordered logit regression, we reveal that mandatory CSR is significantly positively associated with Sustainable Investment (SI) and significantly negatively affects the CRI. The findings indicate that mandatory CSR reporting firms aligned sustainable investment practices with their business operation to combat global warming. Further, we identify channel variables such as green finance and green innovation that play a mediating role in the relationship between CSR practices and the climate risk index. The findings emphasize the strategic imperative in the context of stakeholders' theory for firms to align CSR activities with their long-term strategy, highlighting the contribution of channel variables like green finance and green innovation in tailoring effective CSR activities for sustainability. Therefore, this study contributes in the existing literature by uncovering the integration of mandatory CSR with sustainable investment to combat the climate risk by highlighting the mediating role of green finance and green innovation.

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Introduction

The Paris Summit in 2015 proposed limiting global warming to either 2°C or even 1.5°C to secure habitable land for humanity. Despite the appeals from the international community, global warming persists in escalating, with a reported 5% rise from 2015 to 2022 (Gills & Morgan, 2022). Industrial emissions are widely considered the primary cause of global warming which contributes through greenhouse gases and various industrial discharges (Mahmud et al., 2021). In response, economists and policymakers introduce various policy frameworks for limiting industrial emissions that escalate global warming. The framework offers financial incentives to companies to install sophisticated technology and participate in emission reduction targets voluntarily (Curtin et al., 2017). Further, CSR inspires firms to take proactive steps to overcome industrial discharges as a part of their commitment to Environment, Social, and Governance (ESG) responsibilities (Maalouf, 2024).

The European Union (EU) is also a major part of the global ecosystem that is significantly affected by global warming. The impact of global warming on the EU is diverse and complex, affecting the environmental, social, and economic well-being of its people (Ortega-Gil et al., 2021). The EU responds with a comprehensive approach to alleviate the multifaceted impact of global warming through legitimate policies aimed at overcoming greenhouse gas emissions, reducing fuel use, protecting the environment, and adopting sustainable investment practices (Nilsson et al., 2012). Moreover, the EU in 2014 legislated the disclosure of mandatory CSR reporting for EU countries and member states directed to incorporate into their national law by December 6, 2016 (Doni et al., 2020). Large companies are required to disclose the mandatory CSR under the Non-Financial Reporting Directive (NFRD) for the financial year beginning on or after January 2017 (Von der Heide, 2024).

The surge in CSR disclosure results from new thinking among various bodies that CSR information is increasingly significant to stakeholders and shareholders (Breijer & Orij, 2022). Countries like China, the US, the EU, South Africa, and others, have implemented mandatory CSR reporting rules for selected firms operating within their jurisdictions (Radu et al., 2023). Mandatory CSR strategies are in harmony with the UN's global goals, especially with Sustainable Development Goal 13 (SDG-13), which aims at promoting actions towards the mitigation of climate change impacts (Lu et al., 2021). It also aligns with key sustainability management issues, particularly corporate transparency and accountability in organizational climate change challenges (Poddar et al., 2019).

Mandatory CSR has the potential to scale up funding for green initiatives far beyond public sector involvement; it can also assist in the formidable challenge of closing financing gaps for sustainable development (Hoang, 2024). This means that consistent and transparent CSR investments in green finance instruments help boost market confidence, thereby resulting in an increased market for green finance initiatives (K.-H. Wang et al., 2022). The EU states

compel large firms to produce non-financial reports that cover their environmental effects, thereby pressuring them to support sustainable investment and attract investors in green funds (Carmo & Ribeiro, 2022). Further, Agrawal et al. (2024), and Khan et al. (2023) argue that green finance can help to implement climate projects like renewable energy, energy efficiency, climate adaptive sustainable transportation, and greenhouse gas emissions that contribute to achieving SDG-13.

Green finance and green innovation are increasingly recognized as emerging tools for enhancing mandatory CSR reporting and combating climate risk (Mishra & Sant, 2024). The concept of green finance is to generate and organize financial resources toward investment practices that can improve the environmental sustainability and combat the climate risk. It includes a broad range of financial products and services including lending, investment, insurance and consultancy services, aimed at supporting environmental friendly policies and practices for long-term sustainability (Almeida et al., 2023). Meanwhile, green innovation refers to the development of new products or improved products and services that help to reduce environmental change, enhance efficiency and promote climate sustainability (Mahmud et al., 2021). It aims to address ecological challenges like climate change, pollution, and resource scarcity by introducing eco-friendly solution such as renewable energy technologies, sustainable material and energy efficient systems. By integrating sustainable environmental policies with firm investment decisions, green innovation helps the transition to a sustainable investment with low carbon emissions to combat the climate risk.

Green finance provides the necessary funding for research and development (R&D) of new green innovations for sustainable investment practices (Tolliver et al., 2021). Green finance focuses the projects that are environmentally friendly or have merits towards the environment are considered; hence serving to ensure that green innovation gets the capital it deserves to grow and expand (Q.-J. Wang et al., 2022). This alignment prompts more green innovations with sustainable investment practices that not only increase returns but also support the company's future viability (Shahzad et al., 2021). Firms that adopt Mandatory CSR practices promote green innovation by providing the necessary funding for green projects (Yuan & Cao, 2022), reducing financial risk, creating market demand, encouraging supportive policies, and fostering collaborations (Agrawal et al., 2024). This approach is directly aligned with SDG-13, which focuses on combating climate change and its impacts. These actions are critical in mitigating climate risks and supporting the implementation of mandatory CSR practices for the attainment of SDG-13 (Barua & Aziz, 2022).

This study is contributing significantly to the fields of corporate sustainability, green finance and climate risk by investigating the influence of mandatory CSR disclosures in investing in green innovation and addressing climate risk (Hidayat-ur-Rehman & Hossain, 2024). It highlights the crucial role of CSR in enhancing accountability and transparency by fostering sustainable investment practices, integrating with global priorities like SDG-13 (Udeagha & Ngepah, 2023). By investigating the interplay between mandatory CSR, green finance and green innovation, the study proposes valuable insights into how the corporate sector and policymakers can collectively drive climate actions (Pantos, 2023). The aim is to explore the impact of mandatory CSR disclosures on climate risk (SDG-13), with a focus on climate change mitigation and sustainable investment practices of EU member states. The study defines its objectives in alignment with this aim. Firstly, it analyses how mandatory CSR disclosures promote green finance in implementing green projects to mitigate the climate risk for long-term sustainability. Secondly, the study investigates whether the firms with

mandatory CSR practices support financing green innovations to achieve the SDG-13 targets. Further, the study highlights the role of CSR disclosures in enhancing corporate accountability and transparency in addressing climate change challenges and promoting sustainable investment practices for the attainment of SDG-13. The remaining structure of article is as follows: Literature review and hypothesis development, detailed explanation of data and methodology, presentation of results and discussion, conclusion and managerial implications, study limitations and future research directions.

1. Literature review and hypothesis development

Mandatory CSR refers to the legal requirements of firms to undertake environmental and social objectives in the interest of numerous stakeholders. Mandatory CSR regulations require businesses to not only allocate funds for CSR projects but also invest in sustainable projects to mitigate the risk of climate change for long-term sustainability (Bagh et al., 2024; Bryant et al., 2020). Zu (2023) explains that mandatory CSR practices firms have been encouraged to pursue sustainable investment initiatives to address the climate risk advocated by SDG-13. The sustainable investment initiatives include the adoption of environmental regulation and sustainability, environmentally friendly initiatives, social responsibility (Falcone, 2020), and robust governance practices to address the climate challenges for long-term sustainability (Pinkse & Kolk, 2012).

In lens of stakeholder theory, mandatory CSR reporting plays a crucial role in promoting sustainable investment to address the SDG-13 which targets the climate risk. The Corporate Sustainable Reporting Directive (CSRD) in EU characterizes this approach to address the global climate related challenges (Busch et al., 2021). The CSRD requires the companies to report standardized, data on their environmental and social impact to ensure transparency and promote sustainable investment for addressing risk and opportunities associated with climate change (Zu, 2023). The approach shifts toward a more sustainable economic environment, aligning corporate decisions with climate risk mitigation strategies. Moreover, the CSRD guide corporate sector in integrating ESG compliance into their investment strategies, reflecting stakeholder interest for responsible corporate practices (Falcone, 2020). This integration not only promotes the sustainable investment but also enhances accountability and transparency that help to address the climate related issues.

Stakeholder's theory emphasizes not only the wealth of shareholders (Annesi et al., 2024) but the real worth of a company based on the stakes of its stakeholders such as employees, customers, suppliers, communities, and the environment in which it operates (Kaler, 2006). This holistic approach promotes sustainable business practices that are beneficial for different segments of business sustainability (Bocken et al., 2014). The stakeholder theory provides a foundation for mandatory CSR reporting, which emphasizes transparent reporting to build trust and confidence among stakeholders by addressing the ESG factors for long-term community interest (Breijer & Orij, 2022). The mandatory CSR reporting emphasizes that firms incorporate the ESG factors into their business operations (Curtin et al., 2017); this approach brings trust and loyalty of shareholders in support of firm initiatives to mitigate the risk of climate change (Doni et al., 2020). Bonacorsi et al. (2024) explains that integrating ESG factors and addressing climate issues can contribute to long-term sustainability that helps to reduce climate risk Further, Maalouf (2024) documents the firms that adopt the mandatory CSR practices have a competitive edge by proactively managing and reporting

ESG performance that assists to mitigate the climate risk and step forward to combat global warming. Therefore, we propose the first hypothesis.

Hypothesis 1: From the perspective of stakeholder theory, mandatory CSR reporting promotes sustainable investment that significantly helps to address SDG-13, which focuses on mitigating the climate risk.

Mandatory CSR practices emphasize promoting sustainable development to mitigate the risk of climate change. The integration of mandatory CSR with green finance represents the shift towards sustainable business operations and environmental stewardship (Mohd & Kaushal, 2018). Mahmud et al. (2021) argue green finance is considered the most effective tool of financing to promote sustainable investment for long-term sustainability and growth to mitigate climate risk. Siri and Zhu (2019) are reported that mandatory CSR firms use green finance to invest in green projects to fulfil the legal requirement while enhancing environmental sustainability to mitigate climate risk. Mandatory CSR reporting firms contribute to emerging stakeholder theory by financing green finance to economics, social, and environmental projects for numerous stakeholders to combat the challenges of climate risk (Von der Heide, 2024). Firms that adopt mandatory CSR practices establish clear guidelines and standards for sustainable investment strategies that help to fight climate risk (Agrawal et al., 2024). Further, Hoang (2024) explains that CSR practices firms integrate green finance with a firm long-term investment policy by introducing green projects and sustainable initiatives that are more fruitful to reduce global warming.

The integration of mandatory CSR with green finance plays a significant role in enhancing sustainable investment and mitigating climate risk (Roncoroni et al., 2021). Mandatory CSR eases the development of green finance mechanisms, such as green bonds and green funds (Sadiq et al., 2022), to channel capital into sustainable investment initiatives that reduce carbon emissions and promote a healthier environment for society. The firms that adopt the mandatory CSR are in a better position to initiate the sustainable investment projects finance by green funding, effectively addressing the climate risk (Bonacorsi et al., 2024).

Hypothesis 2: The alignment of mandatory CSR practices with green finance not only promotes sustainable investment practices but also assists in mitigating climate risk.

The mandatory CSR practices firms are intensively investing in green innovations by offering sustainable products and services for future growth and sustainability (Maalouf, 2024). Radu et al. (2023) explains that mandatory CSR is a more effective tool to drive green innovations and encourage companies to implement sustainable practices that are beneficial for both society and the environment. Sahu et al. (2024) explain that mandatory CSR practices help to align business practices with green innovation initiatives to meet the regulatory requirements (Bocken et al., 2014) and stakeholders' expectations that assist in achieving long-term sustainability and contribute to combating climate risk (Tolliver et al., 2020). The firms that invest in green innovations more effectively contribute to long-term business sustainability by investing in sustainable solutions and reducing environmental risks (Poddar et al., 2019). The alignment of mandatory CSR with green innovation significantly reduces the climate risk by forcing firms to promote sustainable initiatives and technologies for environmental sustainability (K.-H. Wang et al., 2022). Hoang (2024) argues that the integration of CSR with green innovation ensures that businesses actively invest in green innovation projects that can positively affect long-term sustainability. This approach may enhance corporate sustainability by addressing climate risk and protecting ecosystems and

communities from the negative effects of climate change (Bonacorsi et al., 2024). The integration of CSR with green innovation plays a significant role in the global effort to combat climate change, promoting a more sustainable and resilient future (Sahu et al., 2024).

Hypothesis 3: The alignment of mandatory CSR practices with green innovation not only promotes sustainable investment practices but also assists in mitigating climate risk.

2. Data and methodology

The EU has recently introduced a concept of mandatory CSR reporting to enhance corporate transparency and environmental sustainability to achieve SDG-13. The EU introduced the NFRD in 2014 as the cornerstone of mandatory CSR reporting for large companies to report in their financial statements (Busch et al., 2021). The EU member states are directed to implement mandatory CSR reporting from 2017 within their geographical and legal boundaries (Breijer & Orij, 2022). From 2017 all large companies having more than 500 employees, and more than 20 million assets are required to include mandatory CSR reporting into their financial statements (Von der Heide, 2024). This study uses the data of large companies registered in EU member states from 2012 to 2022 to examine the impact of mandatory CSR reporting on climate risk. The entire sample consists of 1,854 companies and is divided into two phases: the pre-mandatory CSR reporting period from 2012 to 2016 and the post-mandatory CSR reporting from 2017 to 2022. The Bloomberg terminal database is used to extract the data for analysis. The sample is refined by excluding 430 foreign firms to reduce the chance of repetition and financial entities due to their financial market dynamics (Doni et al., 2020). Further, 266 firms that voluntarily disclosed CSR information, along with 190 firms with missing data for any variables used in the study were excluded. This refinement resulted in a final sample of 968 firms, consisting of 572 treated firms and 396 control firms, based on yearly observations from the complete dataset.

2.1. Climate risk index

The Germanwatch is a private organization based in Germany and is also known for global equity, sustainability, and climate change. Germanwatch has constructed the Climate Risk Index (CRI) to measure the global climate vulnerabilities. Germanwatch's CRI is widely used and cited in global climate policy formulation, corporate reports, and academic research (Bonacorsi et al., 2024). The country with the lowest rank is considered the least vulnerable and the country with the highest rank is considered the most vulnerable (Busch et al., 2021).

2.2. Sustainable investment index

Sustainable investment is quantified by developing the Sustainable Index (SI). This index integrates the investment value of each firm and the corresponding ESG score for each firm in our sample. A higher SI score indicates greater sustainability within the firms (Zu, 2023). The statistical model used to determine the sustainable investment index value for each investment of a firm is detailed as follows:

$$SI_i = \int (Investment\ Value_i, ESG\ Score_i) \quad \text{Eq.1}$$

Where:

- SI_i - represents the Sustainable Index value for $investment_i$;

- $investment\ value_{\ i}$ - the value of $investment_i$ of each firm; and
- $ESG\ Score_i$ is the ESG score associated with $investment_i$. This model combines both the monetary value and the sustainability performance to provide a comprehensive measure of sustainable investment (Breijer & Orij, 2022).

2.3. Channel variables

The channel variable green finance index is constructed to evaluate the mediating effect of green finance on the mandatory CSR practices on the CRI. This index is designed by the parameters of the set of financial relations shown by Eq. 2 (Siri & Zhu, 2019) and the estimated outcome of ordered logit regression is disclosed in Appendix B.

$$Green\ Finance\ (GF)Index = \beta_0 + \beta_1 \times green\ investment_{i,t} + \beta_2 \times green\ finance_{i.t} + \beta_3 \times sustainable\ loan\ portfolio_{i,t} + \beta_4 \times ESG\ rating\ score_{it} + \varepsilon_{i.t} \quad \text{(Eq. 2)}$$

Similarly, the ordered logit regression model employed in building the green finance innovation index or the GI Index shows that measuring the firm's environmentally sustainable finances or the firm's green performance. This index is developed with the utilization of green investment and engagement which is expressed by Eq. 3. This index is designed by the parameters of the set of financial relations shown by Eq. 2 and the estimated outcome of ordered logit regression is disclosed Appendix B.

$$Green\ Innovation(GI)\ Index = \beta_0 + \beta_1 \times \text{R\&D Investments in green technologies}_{,t} + \beta_2 \times \text{Patents for green technologies}_{,t} + \beta_3 \times \text{Revenue from green products}_{,t} + \beta_4 \times \text{Sustainability engagement}_{,t} + \beta_5 \times \text{Green innovation awards score}_{,t} + \beta_6 \times \text{Environmental impact assessment score}_{s,t} + \varepsilon_{i,t}. \quad \text{(Eq. 3)}$$

2.4. Propensity score matching approach

Initially, we employ the Propensity Score Matching Approach (PSMA) to deal with the problem of non-random selection of treated firms and overcome the potential biases creating form observable difference between treated firms and control firms (Falcone, 2020). As for the pre-CSR mandatory period, the first-stage logit regression is used to estimate the likelihood of a firm's entry into the treated group according to their attributes such as the market value of equity, corporate donations, equity turnovers, state ownership, stock return, and accounting profitability (Von der Heide, 2024). The testing results of the first-stage logit regression can be found, with the Pseudo R2 results listed in Panel A of Appendix A that indicate 34 %. We also reveal that the probability of treated firms is positively associated with various factors like the market value of equity, accounting profitability, state ownership, political connection, and analyst forecast, and a negative association with corporate donations (Carmo & Ribeiro, 2022). After estimating the propensity score of each treated firm using the logit model's predicted probabilities, we conduct matching with control firms through the nearest neighbour matching algorithm (Yuan & Cao, 2022). This matching mechanism involves a caliper width of 0.2 times the standard error of the propensity score and permits

replacement. The outcomes shown in Panel B of Appendix A explain that the difference in average firm attributes between treated firms and PSMA control firms is statistically insignificant (Q.-J. Wang et al., 2022).

2.5. Empirical analysis

The ordered logit regression model is used to test the influence of mandatory (CSR) reporting on the CRI, a global climate risk assessment, which is compatible with SDG-13 (Bonacorsi et al., 2024). In the first step, we examine the endogeneity between a CRI and mandatory CSR reporting. This is done by running a regression of the CRI on three main regressors: A dummy variable label for post-period (Post), a dummy variable supposing that firms are involved in mandatory CSR practices (Treatment firms), and the interaction term of Post and Treatment firms (Zu, 2023).

Further, we also examine the influence of mandatory CSR on sustainable investment to test whether sustainable investment has a significant role in the implementation of CSR practices (Annesi et al., 2024) and helps to combat global warming. To take account of the possibility that changes are specific to some industries, we include industry fixed effects (Breijer & Orij, 2022). We also include controls for firm characteristics that might correlate with the firm performance based on firm size, cash holdings, and state ownership.

$$\text{CRI} = \beta_0 + \beta_1 \times Post + \beta_2 \times Treatment\ firms + \beta_3(Post \times Treatment\ firms) + \beta_4 \times \sum Control + \varepsilon \quad \text{(Eq. 4)}$$

$$\text{SI} = \beta_0 + \beta_1 \times Post + \beta_2 \times Treatment\ firms + \beta_3(Post \times Treatment\ firms) + \beta_4 \times \sum Control + \varepsilon \quad (Eq. 5)$$

In our regression model, the post-treatment firms are the variable of primary concern, which is represented as β3, an interaction term of (post × treatment firms). The interaction term captures the variation in the CRI for our treatment firm's comparison to the change for our benchmark firms following the CSR disclosure mandate (Doni et al., 2020). A positive (negative) sign of B3 coefficient indicates an increase (decrease) in CSR after the mandate. To obtain high reliability of our results we employ standard errors that are both robust and clustered by the firms for all the variables at the firm's level. It assists in addressing correlation issues within the firms and also strengthens our statistical inferences (Gills & Morgan, 2022).

3. Results and discussion

3.1. Descriptive statistics

Table no. 1. presents the descriptive statistics of the variables under study, with emphasis on the result from the propensity score matching sample. As part of the data analytic preparation, all variables have been winsorized at the one and ninety-nine percentiles of the corresponding data set (Maalouf, 2024). The mean value of the dependent variable CRI is (0.283), with a corresponding median value of (0.384) and with lower standard deviation of (0.154). These figures strongly suggest a pronounced level of climate risk variables in European countries.

Table no. 1. Descriptive statistics panel A

Variable	Mean	Median	Std. Dev	P25	P75
CRI	0.283	0.384	0.154	0.153	0.402
SI	0.583	0.350	0.238	0.086	0.397
GFI	1.042	1.352	1.437	0.153	1.353
GII	1.365	1.769	1.652	0.437	1.721
Size	14.65	22.85	7.639	7.982	27.67
Trade credit	0.176	0.274	0.321	0.065	0.452
Sales growth	0.354	0.541	0.376	0.263	0.398
Debt	0.253	0.375	0.276	0.174	0.384
InsHold	0.374	0.465	0.167	0.193	0.642
Donation	0.046	0.136	0.166	0.059	0.084

Further, the SI mean value is (0.583) with a medium value (0.350) corresponding lower standard deviation (0.238) indicating that most EU firms are strictly implementing ESG compliance with their investment initiative for long-term sustainability (Mahmud et al., 2021).

3.2. Correlation analysis

Table no. 2. presents a correlation analysis among various variables, including CRI (a measure of climate risk), SI (a measure of sustainable investment), channel variables GFI and GII, firm-specific attributes (Size, Trade credit, Sales growth, Debt, InsHold), and a philanthropic variable (Donation) (Carmo & Ribeiro, 2022). Notably, the CRI exhibits negative correlations with GFI (-0.487) and GII (-0.453) suggesting that higher green finance and green innovation reduce the climate risk (Hoang, 2024; Khan et al., 2021; Naseer et al., 2024). However, the negative correlation found between CSR and SI (-0.397), indicates that sustainable investment is a step forward to combat global warming (Lu et al., 2021). Further, a positive relationship was found between SI and channel variables GFI (-0.561) and GII (-0.636), which explains that our mediating variables support to implement the sustainable investment practices (Maalouf, 2024). The correlation matrix provides a comprehensive overview of the interplay between the control variables, offering valuable insights into potential relationships and dependencies within the data set (Poddar et al., 2019).

Table no. 2. Correlation analysis among the variables

Variables	CRI	SI	GFI	GII	Size	Trade credit	Sales growth	Debt	InsHold	Donation
CRI	0									
SI	-0.397[a]	0								
GFI	-0.487[a]	0.561[a]	0							
GII	-0.453[a]	0.635[a]	0.573[a]	0						
Size	-0.462[b]	0.386[c]	0.488[a]	0.433[a]	0					
Trade credit	-0.351[a]	0.290[b]	0.387[a]	0.364[a]	0.434[a]	0				
Sales growth	-0.560[a]	0.416[a]	0.446[b]	0.529[a]	0.352[a]	0.545[a]	0			
Debt	-0.449[b]	0.447[a]	0.432[a]	0.345[c]	0.521[a]	0.453[a]	0.549[a]	0		
InsHold	0.385[a]	0.311[b]	0.387[a]	0.483[a]	0.687[a]	0.354[a]	0.556[a]	0.378[a]	0	
Donation	-0.485[a]	0.265[c]	0.336[b]	0.355[a]	0.430[b]	0.354[b]	0.440[a]	0.574[b]	0.263[a]	0

a, b, and c represent statistical significance at 1%, 5% and 10% thresholds, respectively.

3.3. Empirical analysis

Table no. 3. shows the results obtained by using the propensity score matching approach in Eq. 4. The findings indicate that the treated group significantly negatively impacted the CLR (-0.024) in column 1, indicating that firms adopt the mandatory CSR reporting more significantly contributed in the reduction of climate risk (Radu et al., 2023). The insignificant effect of the post coefficient explains that benchmark firms do not experience any change to the change of CSR disclosure shocks (Tolliver et al., 2020). The negative effect of the coefficient of interaction term of (Treated × Post) on CRI (-0.046) in column 1 indicates that mandatory CSR reporting has a more significant role in reducing the climate risk and supporting the sustainable climate on the landscape (Sahu et al., 2024).

Table no. 3. Analysis of mandatory CSR effect on CRI

Variables	**CRI 1**	**SE 2**	**CRI 3**	**SE 4**
Treated	-0.024***	0.002		n.a.
Post	-0.003	0.021		n.a.
Treated × Post	-0.046***	0.003	-0.046***	0.002
Size	-0.025***	0.001	-0.032***	0.001
Trade credit	0.065**	0.026	0.043**	0.024
Sales growth	0.045**	0.015	0.033**	0.015
Debt	0.053***	0.024	0.064**	0.016
InsHold	0.025***	0.003	0.035**	0.003
Donation	0.015**	0.004	0.015*	0.002
Fixed effect	Industry		Firms & year	
N (Firms-year)				
Adj. R^2	0.164		0.217	

***, **, and * represent statistical significance at 1%, 5% and 10% thresholds respectively.

In correspondence with Table no. 3., Table no. 4. represents the effect of mandatory CSR reporting on sustainable investment (Hidayat-ur-Rehman & Hossain, 2024). The independent variable mandatory CSR reporting measure by (Treated × Post) on SI (0.066) more significantly positively explains the dependent variable sustainable investment after the mandate (Lashitew, 2021). The findings indicate that mandatory CSR reporting encourages firms to adopt sustainable investment practices for long-term growth and prosperity, which may effectively help to reduce the climate risk as proposed in hypothesis 1 (Pantos, 2023).

The findings support hypothesis 1, that mandatory CSR firms allocate the resources for numerous CSR initiatives under the CSR reporting mandate, potentially assisting in the optimal allocation of resources for a more sustainable environment for all living hoods on the earth (K.-H. Wang et al., 2022). The findings indicate that implementation of mandatory CSR reporting more significantly contributes to the reduction of climate risk on the earth and supports a more sustainable environment for future well-being (Agrawal et al., 2024). Overall, the findings indicate the significance of mandatory CSR reporting requirements in a broader economic change to promote a sustainable environment on the landscape (Barua & Aziz, 2022).

Table no. 4. Analysis of mandatory CSR effect on SI

Variables	SI 1	SE 2	SI 3	SE 4
Treated	0.034***	0.003		n.a.
Post	0.045	0.031		n.a.
Treated × Post	0.066***	0.004	-0.024***	0.001
Size	0.041***	0.002	-0.031***	0.002
Trade credit	0.033**	0.021	0.033**	0.021
Sales growth	0.034**	0.014	0.032**	0.014
Debt	0.043***	0.023	0.044**	0.013
InsHold	0.023***	0.001	0.032**	0.002
Donation	0.012**	0.003	0.013*	0.001
Fixed effect	Industry		Firms & year	
N (Firms-year)				
Adj. R^2	0.165		0.214	

***, **, and * represent statistical significance at 1%, 5% and 10% thresholds respectively.

3.4. Mediation analysis

The mediation analysis is conducted by following Baron & Kenny (1986) three-step approach for examining the relationship between the dependent variables CRI independent variable mandatory CSR, and mediating variables like GR and GI to test hypothesis 2 and hypothesis 3.

$$\text{Mediator} = \beta_0 + \beta_1(\text{Treated} \times \text{Post}) + \beta_2(\text{Treated}) + \beta_3(\text{Post}) + \beta_4(\sum\text{Control}) + \varepsilon. \quad \text{Eq. 6}$$

$$\text{CRI} = \beta\_0 + \beta\_1(\text{Treate} \times \text{Post}) + \beta\_2(\text{Treated}) + \beta\_3(\text{Post}) + \beta_4(\sum\text{Control}) + \varepsilon. \quad \text{Eq. 7}$$

$$\text{CRI} = \beta_0 + \beta_1(\text{Treated} \times \text{Post}) + \beta_2(\text{Treated}) + \beta_3(\text{Post}) + \beta_4(\text{Mediator})) + \beta_5(\sum\text{Control}) + \varepsilon. \quad \text{Eq. 8}$$

3.5. Mediation analysis of green finance and green innovation

Equation 6 is used to analyse mediating variables, green finance (FC) and Green Innovation (GI), and the result is shown in Table no. 5. columns 1 to 4 respectively. As depicted in Table no. 5., column 1 (0.035), there is a significant positive relationship of (Treated × Post) with mediating variable GF (Breijer & Orij, 2022), which means that the mandatory CSR reporting firms use green finance for raising finance externally for the sustainable initiatives. Further, in Table no. 5., a significant positive effect of (Treated × Post) with mediating variable GI (0.018), indicates that mandatory CSR practices firms invest more in green innovation for long-term sustainability to combat the climate risk (Maalouf, 2024).

Table no. 5. Mediation analysis panel A

Variables	**GF** **(1)**	**CRI** **(2)**	**GI** **(3)**	**CRI** **(4)**
Treated × Post	0.035***	-0.057***	0.018***	-0.054***
Treated	0.017**	-0.034**	0.035**	-0.026**
Post	0.045**	-0.025**	0.026**	0.018**
GF		-0.026**		
GI				-0.024**
Controlled	Yes	Yes	Yes	Yes
Fixed effect	Industry	Industry	Industry	Industry
N				
Adj.R^2	0.16	0.29	0.14	0.19

***, **, and * represent statistical significance at 1%, 5% and 10% thresholds respectively

Therefore, the findings provide support to the study hypotheses 2 and 3 and indicate that channel variables GF and GI are significantly associated the mandatory CSR reporting (Bonacorsi et al., 2024). Equation 8, which relates to the mediating variable CRI and, is previously estimated and is reported here in Table no. 3, column 1 shows that mandatory CSR (Treated × Post) significantly negatively affects the CRI (-0. 046) (Radu et al., 2023).

Upon the inclusion of GF and GI in equation 8, a significant negative effect of (Treated × Post) on CRI (-0.057) and (-0.054) are revealed, as presented in Table no. 5., columns 2 and 4 respectively (Agrawal et al., 2024). However, it is noted that the magnitude of the coefficient in Eq. 8 for (Treated × Post) and CRI (-0.057) and (-0.054) is higher than the magnitude observed in Eq. 8 for (Treated × Post) and CRI (-0.046) in Table no. 3, column 1 respectively (Hoang, 2024). The increase in the magnitude of the coefficient on (Treated × Post) in Table no. 5 is attributed to the inclusion of GF and GI in Eq. 8, supporting the notion that GF and GI partially mediate the effect of the CSR reporting mandate on CRI (Maalouf, 2024). This finding aligns with and supports Hypotheses 2 and 3, respectively. The findings guide that mandatory CSR practices firms invest through green finance and green innovation to combat global warming (Radu et al., 2023).

Conclusions and managerial implications

This research study analyses the impact of mandatory CSR reporting on the CRI, a metric for climate risk aligned with the SDG-13. Despite the mandate not obligating firms to spend on CSR activities, the findings indicate that firms included in the 2017 mandatory CSR disclosure successfully contribute to a reduction of climate risk on the earth. The findings suggest that mandatory CSR disclosure promotes a sustainable investment, thereby effectively contributing to the reduction of global warming. The results indicate a notable contribution to the decline of climate risk in EU countries by firms adhering to the 2017 CSR disclosure mandate, despite the absence of a requirement to spend on CSR initiatives. The findings indicate that mandatory CSR disclosure is aligned with accelerating more sustainable investment, eventually leading to a significant reduction in climate risk.

To investigate the dynamics of the association between the CRI and mandatory CSR disclosure, we mark the channel variables like green finance and green innovation. A novel index of each channel variable is introduced to examine the role of the mediating variable in the relationship between CRI and CSR disclosure. Channel variables like green finance and green innovation have been identified to mediate the dynamics of the association between the CRI and mandatory CSR disclosure of EU countries. The findings highlight that mandatory CSR disclosure not only helps to reduce global warming but also underlines the significance of channel variables, particularly green finance and green innovation to combat the climate risk. Further, the study finds that channel variables support the mandatory CSR practices of firms to invest in sustainable investment initiatives that directly and indirectly help to reduce climate risk.

Based on the findings this study proposed the following important managerial implication for organizations to adopt the mandatory CSR reporting. Managers should understand that the adoption of mandatory CSR reporting is paramount for sustainable investment initiatives that contribute to the reduction of global warming. Consequently, mandatory CSR practices remain a significant component of the companies' strategic management, aiming not just at the fulfilment of the legal requirements but creating sustainable investments as well.

Recognizing the nuanced dynamics identified in this study, such as green finance and green innovation allows managers to tailor their CSR initiatives effectively. Thus, taking into consideration the significance of these channel variables, businesses can adapt the mandatory CSR practices, making it more efficient in contributing to the development of social sustainability and improving the organizational viability and innovation of businesses in the long term.

Study limitation and future research

Although this research study explains valuable insight into the relationship between mandatory CSR and climate risk index, it is pertinent to consider some limitations that may guide further research directions. Firstly, the research is based on the 2014 mandatory CSR disclosure; the results could be contingent on the available circumstances of the period. Future research could be conducted on the longitudinal influence of mandatory CSR reporting over different time horizons to better understand the impact of sustainable investment on global warming.

The channel variables recognized in this study provide a substance for further investigation, yet it is feasible that there may be other mediating variables that influence the relationship between mandatory CSR disclosures and the climate risk index. Moreover, the study primarily examines publicly listed companies; future research could extend the analysis to include private companies and diverse industries to enhance the generalizability of the findings. Despite these limitations, this study provides important insights for managers and proposes a road-map for future research for understanding the dynamic interplay between CSR practices and global warming.

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Appendix A: Propensity score of treated and match control firms

	Panel-A			Panel-B		
Variables	Coeff	t-stat	Treated	control	t-state	p-value
MV	0.817***	(0.075)	16.78	16.97	-0.631	0.449
Turnover	-0.036	(0.041)	7.19	7.87	-1.154	0.353
Return	0.077	(0.034)	0.868	0.947	0.540	0.594
ROE	1.686***	(0.647)	0.215	0.249	-0.087	0.837
State	1.068**	(0.363)	0.464	0.410	-1.308	0.285
Donation	-2.133*	(1.357)	0.037	0.039	-0.051	0.826
Inst Hold	0.526***	(0.214)	0.673	0.637	0.715	0.493
Analyst	0.436***	(0.0436)	2.475	2.430	0.484	0.535
Fixed effects	Industry & year					
Pseudo R^2	0.34					

. ***, **, and * represent statistical significance at 1%, 5%, and 10% thresholds respectively.

Appendix B: Order Logit Regression to construct the channel variables index

	GF		GI	
	Coeff	t-stat	Coeff	t-stat.
GI	18.65	(2.0781)		
GF	27.56	(2.0981)		
SLP	9.783	(1.784)		
ESG	17.56	(1.619)		
R&D			24.632	(1.863)
RGP&S			16.943	(1.074)
% change in patents			8.226	(0.0619)
Green innovation award			6.093	(0.0242)
Envt impact score			7.974	(0.0682)
Fixed Effect	Firm & year		Firm & year	
Pseudo R^2	0.352		0.317	