An Empirical Investigation into the Impact of Climate Risk on Analyst Forecast Accuracy: The Moderating Role of ESG Performance

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ABSTRACT
This study draws on a sample of non-financial A-share listed firms in China from 2015 to 2024 to examine the impact of physical climate risk (CR) on the accuracy of sell-side analysts' earnings forecasts and to test whether corporate environmental, social, and governance (ESG) performance plays a moderating role. CR is measured by the standardized deviation of the annual average temperature in the firm's registered location from the historical baseline period of 1973-1982. Corporate sustainability practices are proxied by Huazheng ESG ratings. A fixed-effects panel model is employed, controlling for firm size (lnSize), profitability, ownership concentration, and other covariates. Empirical results show that greater regional climatic anomalies are significantly associated with larger analyst forecast errors (FERROR), indicating that climate shocks impair the information intermediation function of capital markets by exacerbating operational uncertainty and information asymmetry. A higher ESG rating effectively mitigates this adverse effect: for each one-point increase in the ESG score (on a 1-9 scale), the marginal impact of CR on forecast error declines by approximately 10.4%. This finding supports the view that ESG enhances the transparency of non-financial disclosures and builds reputational capital, thereby providing analysts with a more reliable informational foundation amid environmental disturbances. Robustness checks using a subsample further confirm the reliability of these conclusions.

Keywords: *Climate risk, Accuracy of analyst's prediction, ESG performance, Information asymmetry, Regulatory effect.*

1. INTRODUCTION

In recent years, the frequent occurrence of extreme weather events is reshaping the business environment of enterprises and the operating logic of capital markets in an unprecedented way [1]. Physical climate shocks such as abnormal temperature, floods and droughts not only directly interfere with the stability of supply chain, asset utilization rate and production efficiency, but also pose a severe challenge to the information processing ability of market participants by intensifying information asymmetry and operational uncertainty [2]. In this context, as a key information intermediary in the capital market, the accuracy of the seller's analyst's profit forecast has become an important indicator to measure the information efficiency of the market [3]. When the region where the enterprise is located encounters a climate disturbance that significantly deviates from the historical normal, the historical financial model and public disclosure information that analysts rely on to build expectations may quickly fail, leading to the expansion of the forecast deviation [4]. Especially in China, an emerging market with vast territory, diverse climate types and the evolution of non-financial information disclosure, how CR penetrates the enterprise boundaries and influences the judgment of external information user needs systematic empirical test [5].

Enterprise environment and ESG performance are increasingly regarded as important mechanisms to alleviate external shocks and enhance transparency and resilience [6]. Theoretically, enterprises with high ESG rating generally have better risk management system, more proactive non-financial information disclosure and stronger

communication ability with stakeholders. These characteristics may provide additional signal support for analysts during climate disturbance, thus buffering the decline of prediction quality [7]. Previous studies have discussed the influence of CR on enterprise performance and the effect of ESG on analyst behavior. However, the existing research on how physical CR affects the prediction accuracy through information channels and whether ESG plays a regulatory role is still insufficient [8]. The existing literature mostly relies on the rough proxy variables at the national or industry level, and lacks the detailed description of the climate exposure of the enterprise registration place; At the same time, the understanding of the mechanism of ESG is often mixed between valuation effects and operational resilience, so it is difficult to strip its pure information value [9].

In this paper, China A-share non-financial listed companies from 2015 to 2024 are taken as samples, and the regional average annual temperature deviation based on the historical reference period is used as a measure of physical CR. Combined with the ESG rating data of CSI, a fixed effect panel model is constructed. This paper empirically tests the influence of CR on analyst's earnings forecast error, and focuses on the moderating effect of ESG performance.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Information asymmetry theory provides basic logic for understanding how CR interferes with analysts' judgment. The business disturbance caused by climate shock is first grasped by insiders, while it is difficult for external analysts to correct their expectations in time due to the lack of real-time and fine-grained non-financial information, which leads to the expansion of forecast deviation. Under this framework, physical CR is regarded as an exogenous source of information friction. At the same time, signal theory points out that enterprises can convey their risk management ability and long-term value commitment to the market through high-quality ESG disclosure, thus alleviating the information disadvantage. Existing research shows that climate anomalies do reduce the stability of corporate profits, and companies with good ESG performance usually have higher transparency and operational resilience. However, few studies put climate exposure, analyst prediction and ESG practice in the same empirical model to test whether ESG plays a regulatory role under climate shock. Based on this, this paper constructs a theoretical chain of "CR- Forecast Error -ESG Adjustment", aiming at revealing the specific mechanism of non-financial information disclosure in improving the information environment of the capital market.

3. RESEARCH DESIGN AND EMPIRICAL ANALYSIS

This study takes China A-share non-financial listed companies from 2015 to 2024 as the initial sample, and the data comes from CSMAR, WRDS and China meteorological science data sharing service platform. In order to ensure the internal consistency and comparability of samples, the original observation values were screened for several rounds. Firstly, enterprises in the financial industry are excluded, because their asset-liability structure and disclosure rules are significantly different from those in the real economy. Secondly, the companies that have been subjected to special treatment (ST/*ST) are excluded to avoid the interference of abnormal information disclosure caused by financial difficulties on the climate-prediction relationship. Again, the missing observations of key variables, including analyst profit forecast, ESG score, climate indicators or control variables, are excluded. Finally, all continuous variables are truncated at 1% and 99% quantiles to reduce the potential impact of extreme values on regression results. Finally, 21,560 effective company-year observations covering 3,872 enterprises were obtained, which constituted a balance panel for subsequent empirical analysis.

In terms of variable construction, the dependent variable FERROR is measured by the ratio of absolute forecast error to actual earnings per share, namely:

$$FERROR_{i,t} = \frac{\left|Mean(FEPS)_{i,t} - FEPS_{i,t}\right|}{\left|FEPS_{i,t}\right|} \quad (1)$$

Where $Mean(FEPS)$ represents the average of the final forecast values of all seller analysts for company i in t year, and MEPS is the earnings per share actually announced by company i in t year. The greater the index value, the more serious the prediction deviation, and the lower the prediction accuracy. Physical CR, the core explanatory variable, is constructed by the annual average temperature deviation of the city where the enterprise is registered. Taking 1973-1982 as the historical reference period, the standard deviation σ of the annual average temperature in each city is calculated, and the difference between the actual annual average temperature from 2015 to 2024 and the average value of the reference period is divided by σ to obtain the standardized temperature deviation index. This method can effectively capture the degree of regional climate anomalies and avoid the cross-regional incomparable problem caused by the use of absolute temperature values.

The performance of ESG as a regulatory variable adopts CSI ESG rating, which covers three dimensions: environment and ESG, and has nine grades (C to AAA). In this study, it is linearly mapped into a continuous variable from 1 to 9, and the higher the value, the better the ESG performance. Control variables include enterprise size (lnSize, natural logarithm of total assets), return on net assets (ROE), shareholding ratio of the largest shareholder (Top1), asset-liability ratio (Lev) and Board size (natural logarithm of the number of directors) to control the potential influence of enterprise fundamentals and governance structure on forecasting behavior.

As for the model setting, Hausman test (χ^2= 79.985, P < 0.001) confirms that the fixed effect model is superior to the random effect model, so the panel regression of individual fixed effect is adopted to control the company characteristics that do not change with time. The benchmark regression model is as follows:

$$FERROR_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 Controls_{i,t} + \mu_i + \varepsilon_{i,t} \quad (2)$$

In order to test the regulatory function of ESG, the interaction between CR and ESG is further introduced, and the extended model is as follows:

$$FERROR_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 Controls_{i,t} + \beta_3 ESG_{i,t} + \beta_4 (CR \times ESG)_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3)$$

"Table 1" shows the descriptive statistical results of the main variables. The mean value of FERROR is 0.839, the standard deviation is 1.035, and the maximum value is 6.749, which reflects the significant heterogeneity of prediction accuracy in the sample period. The mean value of CR is 1.161, and the standard deviation is 1.026, ranging from -0.944 to 3.756, indicating that the intensity of climate disturbance faced by enterprises in different regions is obviously different. The average score of ESG is 4.138, which is between "BBB" and "A", with a standard deviation of 1.058, indicating that the ESG practice of enterprises in China is in the middle level as a whole, but the differentiation is beginning to appear.

Table 1. Descriptive statistics of main variables

Variable	Observation Count	Mean	Standard Deviation	Minimum Value	Maximum Value
FERROR	21,560	0.839	1.035	0.000	6.749
CR	21,560	1.161	1.026	-0.944	3.756
ESG	21,560	4.138	1.058	1.000	7.000
lnSize	21,560	22.722	1.380	20.217	27.007
ROE	21,560	0.054	0.125	-0.562	0.349

Pearson correlation coefficient matrix (see "Table 2") shows that CR is positively correlated with FERROR (r=0.032,p<0.001), which preliminarily supports the hypothesis that CR aggravates the prediction error. ESG and FERROR are also positively correlated (r=0.130), which may be due to the fact that high ESG enterprises are more concerned or the industry itself fluctuates

greatly, so it is necessary to further identify their regulatory role through cross-item regression. The correlation coefficient between other variables is generally lower than 0.5, and the average VIF is only 1.280 (see "Table 3"), which indicates that the problem of multicollinearity is not significant.

Table 2. Pearson correlation coefficient matrix of main variables

Variable	FERROR	CR	ESG	lnSize	ROE
FERROR	1.000				
CR	0.032***	1.000			
ESG	0.130***	-0.019**	1.000		
lnSize	0.189***	-0.089***	0.294***	1.000	
ROE	0.148***	0.070***	0.200***	0.165***	1.000

a Note: ***p < 0.01, **p < 0.05; p-values for two-tailed tests are in parentheses.

Table 3. Variance inflation factor (VIF) test results

Variable	VIF	1/VIF
lnSize	1.845	0.542
Lev	1.579	0.633
ROE	1.185	0.844
ESG	1.168	0.856
Board	1.085	0.922
Top1	1.077	0.929
CR	1.021	0.979
Average VIF	1.280	-

The results of benchmark regression are listed in column (1) of "Table 4": the CR coefficient is 0.317($p<0.01$), which indicates that FERROR increases by about 31.7% on average for every standard deviation of CR. After adding the control variable (column (2)), the CR coefficient rose to 0.359 and remained highly significant, which confirmed that climate shock systematically weakened the forecast quality by aggravating information asymmetry and operational uncertainty. Among the control variables, lnSize and ROE are significantly positive, indicating that large or high-profit enterprises are more difficult to be accurately predicted because of business complexity or performance fluctuation; However, high leverage (Lev) corresponds to lower forecast error, and financial information is more transparent due to debt constraints.

Table 4. Benchmark regression and moderating effect test results

Variable	(1) FERROR	(2) FERROR	(3) FERROR
CR	0.317***	0.359***	0.774***
	(0.040)	(0.044)	(0.123)
ESG	-	-	0.072***
			(0.016)
CR×ESG	-	-	-0.104***
			(0.028)
Control Variables	No	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes
Observation Count	21,560	21,560	21,560
F-statistic	62.170***	49.250***	39.610***

a Note: Robust standard errors clustered at the company level are in parentheses; ***p < 0.01.

See column (3) of "Table 4" for the test results of regulatory effect. The coefficient of interaction term CR×ESG is -0.104($p<0.01$), which indicates that the marginal effect of CR on prediction error is weakened by about 10.4% with each upgrade of ESG performance. Although the main effect of ESG is positive (0.072), its negative interaction with CR is dominant, which proves that high ESG

enterprises can enhance the transparency of information disclosure and operational resilience. This discovery supports signal theory and reputation insurance mechanism: ESG not only transmits long-term value signals, but also plays the role of stabilizer under environmental pressure.

In order to test the robustness of the conclusion, the study limited the sample to 2015-2020 (excluding special shocks such as epidemic situation). The regression results ("Table 5") show that the CR coefficient is still significantly positive (0.297,p<0.01), and the sign and significance of the interaction items remain unchanged, which proves that the main conclusion is not disturbed by events in a specific period.

Table 5. Robustness Test Results (Sub-sample from 2015 to 2020)

Variable	(1) FERROR	(2) FERROR
CR	0.330***	0.297***
	(0.094)	(0.097)
ESG	-	0.068**
		(0.027)
CR×ESG	-	-0.091**
		(0.039)
Control Variables	No	Yes
Individual Fixed Effects	Yes	Yes
Observation Count	10,780	10,780
F-statistic	12.330***	9.500***

a Note: The brackets are the robust standard errors of clustering to the company level; ***p<0.01, **p<0.05。

Model (1) only contains the core explanatory variable CR, and model (2) further controls lnSize, ROE, the shareholding ratio of the largest shareholder (Top1), asset-liability ratio (Lev) and Board size. The results show that the impact of CR on FERROR is still significantly positive in the subsamples excluding special shocks after 2020, and the interaction between ESG and CR remains negatively significant, indicating that the main conclusion is robust.

4. CONCLUSION

Based on the sample of China A-share non-financial listed companies from 2015 to 2024, this study systematically examines the influence of physical CR on the accuracy of seller's analyst's profit forecast, and deeply discusses the moderating effect of ESG performance. The empirical results show that the higher the regional temperature deviates from the historical normal, the greater the FERROR is, which proves that climate shock weakens the function of information intermediary in capital market by aggravating information asymmetry and operational uncertainty. At the same time, it is found that high ESG rating can effectively alleviate the negative impact of CR on the prediction quality: the marginal effect of CR on the prediction error is reduced by about 10.4% on average every time ESG rating is upgraded. The moderating effect is still stable after controlling the variables such as enterprise scale, profitability and ownership structure, and it is verified in the sub-samples from 2015 to 2020.

In terms of mechanism, good ESG performance not only improves the transparency of non-financial information disclosure, but also enables analysts to capture the strategy and resilience of enterprises to cope with climate shocks in a timely manner, and also reduces the interference of market sentiment fluctuations on valuation judgment by accumulating reputation capital. This supports the core view of signal theory and stakeholder theory: ESG is not only a moral choice, but also a strategic tool for enterprises to build credible communication channels and reduce information friction in a complex external environment. Especially under the background that the non-financial disclosure of China capital market is still in the development stage, the information value carried by ESG is more prominent.

The above conclusions have clear policy implications. ① Regulators should speed up the construction of standardized disclosure framework for climate and ESG, and force enterprises to disclose physical CR exposure matching their geographical exposure and countermeasures to avoid information fragmentation and lack of comparability caused by current voluntary disclosure. ② Exchanges and industry associations

can incorporate ESG rating into the evaluation system of analysts' professional ability, and guide them to systematically incorporate non-financial indicators into the forecasting model, thus improving the overall information processing quality. ③ Enterprises themselves should embed ESG management into the risk management system, not just as a public relations or compliance task, especially companies operating in high climate-sensitive areas, and need to enhance external trust through high-quality ESG practices. ④ Academics and data providers should cooperate to develop a multi-source integrated climate -ESG- financial database, so as to provide more detailed and dynamic risk assessment tools for market participants. Only the cooperation of system, enterprise and intermediary can lay a solid foundation for information efficiency of capital market under the new normal climate.

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