Climate risk disclosure and financial market information efficiency: a theoretical analysis based on signal transmission and investor cognition

Yuxin Liu
Department of applied economics, City University of Macau, Macau, 999078, China
m2532744236@163.com

ABSTRACT

Climate risk disclosure has become an important mechanism to link corporate transparency with financial market results. This study combines signal theory, investor cognitive framework and information economics to study how climate-related disclosure can reduce information asymmetry and improve the quality of stock price information. Based on the recent empirical evidence of the global market, we propose a dual-channel model, in which climate risk disclosure affects market efficiency through the response of investors' demand (analyst hedging, institutional investors' participation) and the adjustment of enterprises' supply side (improving transparency and strategic adjustment). The analysis shows that credible climate information disclosure is an important signal, which can reduce the rigidity of investors' expectations and improve price discovery, especially with the support of strong governance mechanism and favorable institutional environment. However, the quality of these disclosed information is restricted by measurement accuracy, regulatory coordination and the characteristics of each company. This study provides a unified theoretical framework, reconciles contradictory empirical results, and provides practical influence for the standardization of corporate disclosure and communication strategies.

Keywords: Climate risk disclosure; Financial market information efficiency; Signaling theory; Investor cognition; Stock price informativeness

1. INTRODUCTION

In recent decades, climate change has changed from an environmental problem to a real financial risk, which needs the attention of financial market workers. Climate-related disasters (such as forest fires, floods and hurricanes) are becoming more frequent and costly. In 2022 alone, the global loss reached $275 billion. At the same time, investors' demand for climate information is increasing. We can see this because more and more funds are invested in sustainable investment in the world. Because of this, regulators around the world, such as the Securities and Exchange Commission of the United States, the European Union and the International Sustainable Development Standards Committee, are now asking or advising companies to formulate rules to explain their climate-related risks.

Even so, it is still unclear whether these risks really help the financial market to operate better. Some studies show that when companies talk about their climate risks, everyone will understand their actions better because there are fewer secrets. Other studies show that when a company produces a lot of carbon, it is difficult to understand the value of its stock, because everything becomes more vague and uncertain. These differences show us that the way climate information helps the market is neither simple nor different for everyone, depending on how investors understand it, how companies react and the rules of each country.

This study fills this theoretical gap by putting forward a comprehensive framework, which combines signal transmission theory, stakeholder-shareholder theory and investor cognition. We believe that climate risk disclosure operates through two interrelated channels: (1) information supply channel, in which enterprises strategically adjust their transparency and operational practices to cope with climate exposure; (2) Information demand channels, investors, analysts and other market participants actively seek and process climate-related signals to improve their value judgments. The interaction between these channels determines whether and to what extent climate information disclosure improves or hinders the quality of price information [1].

Our theoretical analysis gives three main propositions. First of all, reliable climate risk disclosure can be used as a quality signal to reduce information asymmetry, but its signal value depends largely on the accuracy of disclosure and the

credibility of governance. Secondly, the cognitive processing of climate information is influenced by investors' heterogeneity (short-term or long-term tendency, risk aversion and previous beliefs), which determines the market response. Thirdly, institutional factors, such as the severity of rules and legal environment, ease the relationship between disclosure and information quality by affecting the supply of credible information and bringing it into the demand of price.

2. RESULTS AND DISCUSSIONS

2.1 Signaling Theory and Climate Disclosure

Signal theory helps us to understand why companies talk about themselves, sometimes because they want to and sometimes because they have to. This theory comes from labor economics. She said that when some people know more than others, we can reduce this problem if those who know send real signals. In the case of climate disclosure, companies that are beneficial to the environment or manage risks want to show their quality by telling the truth in their reports, which is different from other companies that make less efforts.

However, the climate disclosure signal itself is not always good. In order for the signal to be true and useful, it must be difficult to copy, and it must be able to see and verify it. There is a credibility problem in climate information disclosure: we can't always measure it accurately, especially for range 3 emissions (indirect supply chain emissions), which provides some companies with opportunities for printing management and green cleaning. Companies can carefully choose the tone of the report-use overly optimistic words to cover up their poor performance-which makes the signal less useful. When the standard framework (such as GRI, TCFD) is verified and used by outsiders, it helps to make the signal more realistic because it can prevent the company from overusing the tone.

2.2 Stock Price Informativeness and Information Asymmetry

The information of stock price (SPI) means that the stock price shows important information about the company, not just market noise or mood. When SPI is high, it means that the price is good, which helps to use funds better and manage the business better. Information asymmetry is the difference between what the boss knows and what investors know, which is a big problem for SPI. When investors can't understand the value of the company well, the price becomes less useful, which increases the cost of funds and increases the risk of wrong choice of funds [2].

Climate risk has increased the new challenge of information asymmetry. First of all, climate risks are highly uncertain: their probabilities are constantly changing, depending on the background and following complex rules. Secondly, there are several aspects of climate risk: physical risk (such as storm damage) and transitional risk (such as law, technology or market transition to a low-carbon economy). Finally, climate risks are different for every company, industry or place, so people need different information.

2.3 Investor Cognition and Information Processing

Investor cognition is how people in the market view, understand and use the information they have. Behavioral finance research shows that investors are not perfect thinking machines-they have limited attention, confirmation bias, and they use heuristic methods. In the context of climate disclosure, these thinking problems are very important for several reasons [3]. First of all, climate information is usually complex, technical and forward-looking, and requires special knowledge to understand them. Then, investors have different time frames, different risk preferences and different views on climate change, so they understand the same information in different ways. Finally, there is so much climate information in annual reports, sustainable development reports and media reports that our brains may be flooded, and we only pay attention to certain things, which may lead to boring transactions.

Recent research shows that investors' cognition is very important. Fan found that extreme rainfall increased SPI, mainly because institutional investors, especially those considering short-term factors, needed more information, and because analysts paid more attention to these companies. This means that the climate shock has aroused investors' attention and desire to seek information, making the market more efficient. Similarly, climate risk disclosure helps investors avoid sticking to old ideas-the so-called expectation stickiness-and helps prices change when new information is available.

2.4 The Disclosure-Informativeness Debate: Conflicting Evidence

Using a global sample of the observation results of 73,770 companies from 38 countries, they found that higher carbon emissions greatly reduced SPI, indicating greater information asymmetry. They also show that the governance mechanism-the size, independence, term and nationality of the board of directors-can alleviate this negative impact by improving the

quality of disclosure and reducing opacity. According to this view, climate risk is mainly a factor to increase opacity: companies with large emissions face uncertainty about future costs and responsibilities, which makes the assessment more difficult [4].

In contrast, Fan and Hua, who study China A-share market, found that exposure to climate risk (extreme rainfall) and climate risk disclosure have a positive impact on SPI. They explain this through stronger information demand (attention of institutional investors, reports of analysts) and greater information supply (companies become more transparent). This view regards climate risk as a driving force for improvement: enterprises respond to climate challenges by increasing transparency, and investors reward this transparency through more effective pricing.

These contradictory results tell us that the relationship between disclosure and information depends on several things: (1) how we measure climate risk (emission level, climate events, or the text of disclosure), (2) institutional background (common law and civil law, the strength of rules), (3) the quality of governance, and (4) who is the investor. Our theoretical framework hopes to explain all this by saying when climate disclosure will help or reduce SPI.

3. THEORETICAL FRAMEWORK AND PROPOSITIONS

3.1 The Dual-Channel Model of Climate Disclosure and SPI

We propose a dual-channel model, in which climate risk disclosure affects the quality of stock price information through two interrelated channels:

Channel 1: Increase information supply. Companies facing climate risks respond by making strategic adjustments to improve information transparency. These adjustments include more comprehensive disclosure of emission data, risk management strategies and adaptation plans. Credible disclosure reduces information asymmetry by providing investors with important and useful information. This channel is particularly important when companies are in a high climate risk, when they work in a strict regulatory environment, or when they have good governance rules to ensure the credibility of disclosure.

Channel 2: Enable information request. Climate risk disclosure has attracted investors' attention and triggered positive information seeking behavior. Analysts report more, institutional investors participate more, and market participants incorporate climate-related information into their evaluation models. This cognitive activation reduces investors' expectations and accelerates price discovery. This channel is particularly powerful when weather shocks are visible (such as extreme weather events) or the disclosure is accurate and standardized.

These two channels work together: when the supply is better, the demand increases, and when the demand is greater, it will promote the further improvement of the supply. But they can also develop in different directions-if the information provided is not considered reliable, or if it is "green cleaning", then the demand may not come, or even decline because of more distrust.

3.2 Core Propositions

Based on the two-channel framework and empirical evidence, we put forward the following theoretical suggestions:

Recommendation 1 (signal credibility): The positive impact of climate risk disclosure on SPI depends on the credibility of the information. Credibility is enhanced by external audit, standardized framework (such as TCFD, GRI) and good corporate governance mechanism. Credibility is weakened by vague and repetitive language, inaccurate measurement, and the difference between what is said and what is actually done [5].

This proposal stems from the fact that the governance mechanism constantly changes the relationship between emissions and SPI. It also uses GRI and verification together with evidence to help reduce bad comments in ESG reports.

Proposal 2 (Investor Heterogeneity): The impact of climate disclosure on SPI varies with the type of investors. Short-term institutional investors and analysts who need quick information respond more to climate disclosure than long-term passive investors. Investors' understanding and views on climate change have also changed their understanding of information.

The findings of Fan et al. support the proposal that short-term institutional investors strengthen the positive impact of extreme rainfall on SPI. This is also in line with the ambiguous framework, and investors' confidence in signal reliability will affect the market reaction.

Proposal 3 (Institutional Adjustment): Institutional factors, such as the severity of rules, the quality of law enforcement and information intermediary, are easing the relationship between information disclosure and information content. A stronger institutional environment amplifies the positive impact of credible disclosure by ensuring that the signal is verifiable and there is a price for non-disclosure; On the contrary, in a weak institutional environment, disclosure may be less informative and even misleading.

This suggestion explains the differences between countries observed by Kaul, who found that the negative correlation between emissions and SPI is the strongest in common law countries with high institutional quality. It also supports Mahieux's suggestion that disclosure requirements should be coordinated globally to avoid carbon leakage and measurement arbitrage.

3.3 Boundary Conditions and Contingencies

Our model identifies several conditions that change the relationship between disclosure and SPI:

Accuracy of measures. Sharing indirect emissions (scope 3) is difficult because previous and subsequent activities are shared. If the measurement is inaccurate, this may make the disclosure less useful and even lead to bad results, such as carbon leakage. Companies that are difficult to measure may provide less information, which will reduce SPI.

Harmonization rules. If a country requires more disclosure alone without coordinating with other countries, the company can go to places with fewer rules to produce. This may increase global emissions, but it will reduce the country's SPI [6].

Type of risk. The impact of climate risk disclosure may vary according to the types of risks: long-term risks (such as sea level rise and temperature change) and transitional risks (such as policy changes and technological changes) are easier to report systematically than acute risks (such as forest fires and hurricanes). This shows us that climate risk types have changed supply and demand in our two-channel model.

Characteristics of enterprises. Climate disclosure has the strongest positive impact on SPI, with no pollution, enterprises on land, and those in areas with frequent disasters. This tells us that the additional benefits of disclosure are greatest when the climate exposure is significant, but not too strong, and when enterprises can respond strategically.

4. PRACTICAL IMPLICATIONS AND POLICY RECOMMENDATIONS

Our theoretical framework provides many useful insights for enterprise managers, regulators and investors.

For enterprise managers: the disclosure of climate information must be clear, standardized and verified by outsiders, so that people can trust and investors can rest assured; Companies should not use vague words or ready-made phrases that may look like green cleaning. Major changes such as emission reduction plan, adaptive investment and management reform need to be clearly explained to show good risk management. Companies doing business in multiple countries must pay attention to the differences between rules and try to be consistent in all relationships.

For regulators and standard-setters: disclosure rules must be formulated so that reports can be easily compared and accurate, especially for indirect emissions (scope 3). However, if a country sets stricter rules by itself and other countries don't, it may transfer its emissions to other places (carbon leakage). Regulators need to carefully consider the choice between being very precise and avoiding leakage problems. Requiring external audit and using standardized framework (such as TCFD, ISSB) can make disclosure more reliable and help the market operate better [7].

For investors, climate risk information should be included in the evaluation model and investment decision. However, investors need to carefully check whether this information is reliable, whether there is any verification, whether a good framework is used, and whether it is consistent with other sources. It is also necessary to pay attention to cognitive biases, such as not having enough views on certain things or trusting their ideas too much, so that climate information can be really used for pricing. Working with analysts and talking to companies about the quality of their information can help the market work better.

5. CONCLUSION

This study develops a comprehensive theoretical framework to study how climate risk disclosure affects the validity of financial market information, using signal transduction theory and investor cognition. We suggest that climate information disclosure should operate through two interrelated channels: one is the information supply channel, in which enterprises

improve the transparency of climate risks; The other is the information request channel, in which investors and analysts actively deal with climate signals, reduce expected rigidity and improve price discovery.

Our analysis puts forward three main points: (1) The signal value of climate information disclosure depends on its credibility, which is strengthened by guarantee, standardized framework and good governance. (2) Investors' differences in time range, risk preference and previous beliefs will affect how they deal with climate information; (3) Institutional factors, such as the severity of rules and law enforcement, have eased the relationship between disclosure and information quality. These suggestions are helpful to explain the contradictory results under what conditions climate information disclosure improves or hinders market efficiency.

The framework also shows important conditions that can not be ignored: accuracy of measurement, coordination between rules, risk types and business characteristics. We should consider these problems in our research or work. For managers, regulators and investors, this means that it is very important to establish credible, standardized and well-organized climate communication.

For future research, we should test the dual-channel model with very accurate disclosure data, the measurement standard of investor behavior and the comparison between different countries. It is very interesting to observe how mandatory rules and voluntary rules are mixed, the role of information intermediaries (such as analysts, media, rating agencies), and how investors' way of thinking changes over time.

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