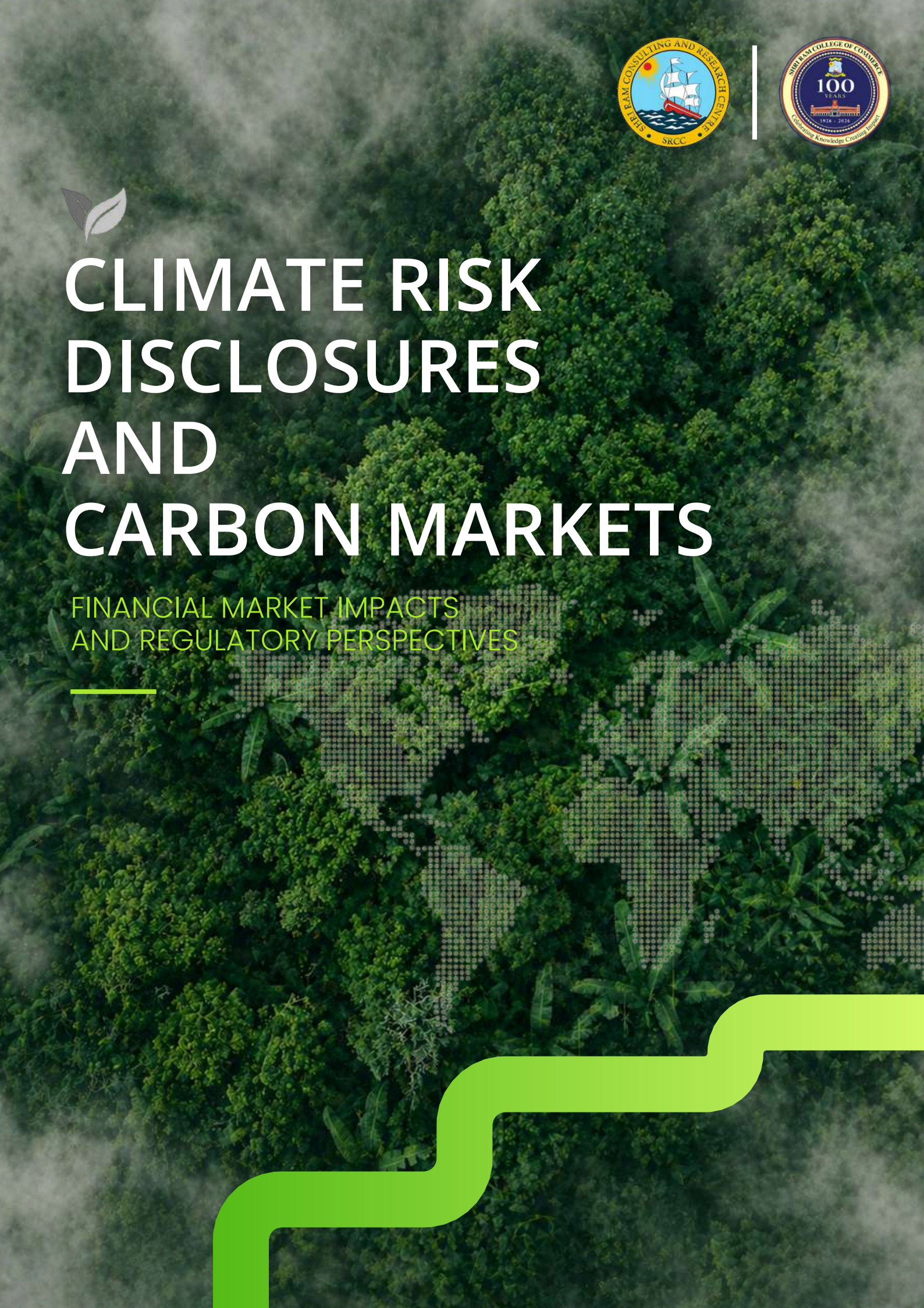

CLIMATE RISK DISCLOSURES AND CARBON MARKETS

FINANCIAL MARKET IMPACTS AND REGULATORY PERSPECTIVES

CREDITS & ACKNOWLEDGEMENT

Published by **Shri Ram Consulting and Research Centre** in 2026

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We are grateful to Shri Ram College of Commerce (SRCC) for providing the academic and institutional ecosystem that enabled this initiative to take shape. We would also like to thank Shri Ram Consulting and Research Centre (SRCRC) for encouraging and supporting the conceptualisation and execution of The Research Report.

We extend our sincere thanks to Nishtha Paharia, Shagun Chaubey, and Yash Sorathiya (Team Leads) for their continued guidance, feedback, and support throughout the development of this series.

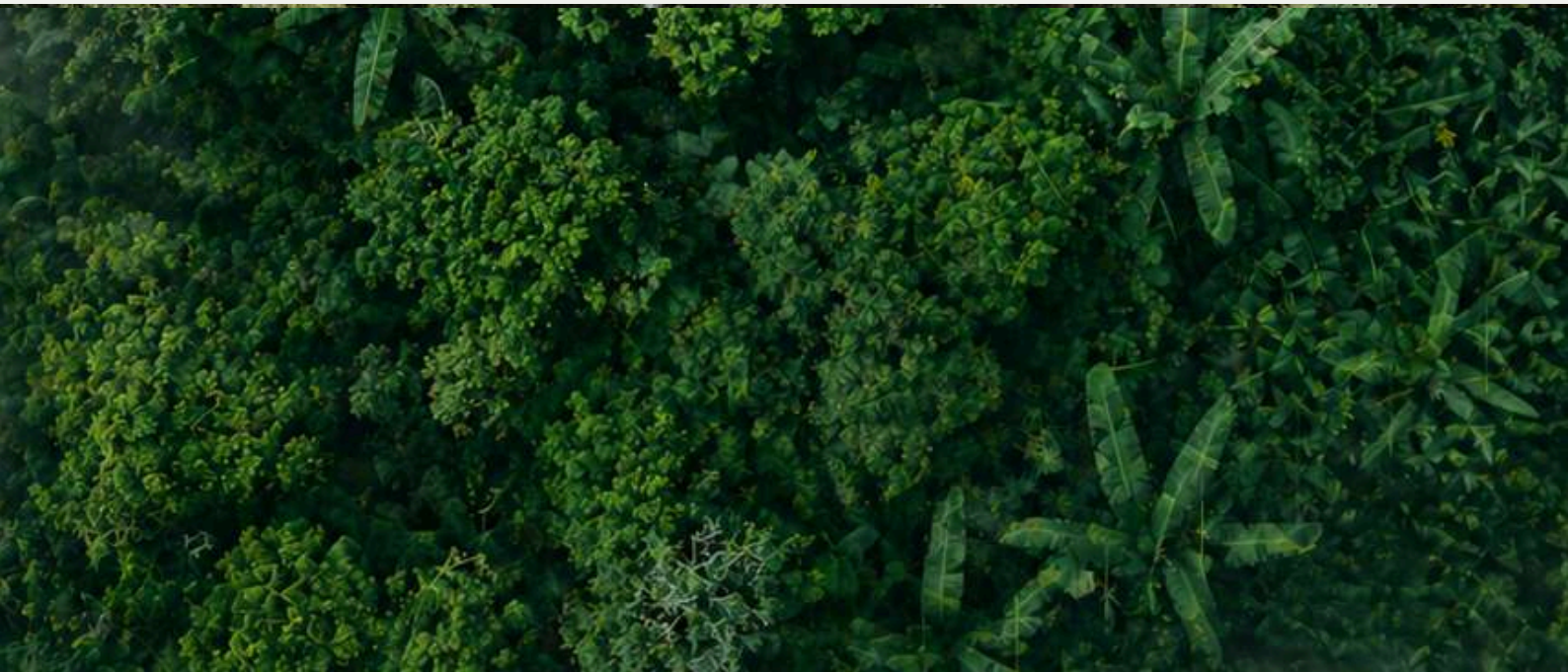


TABLE OF CONTENTS

EXECUTIVE SUMMARY

Climate change has increasingly evolved from an environmental concern into a major financial and economic risk influencing global financial systems, investment behaviour, and capital allocation decisions.This research report examines the growing relationship between climate-related disclosures and financial market outcomes, with particular emphasis on how disclosure quality, carbon pricing mechanism, and evolving regulatory frameworks affect firm valuation, cost of capital, investor confidence, and market efficiency.

The study explores the theoretical and empirical foundations of climate finance by analysing the evolution of climate disclosure regulations such as TCFD, ISSB, CSRD, and SEC proposals, alongside the development of carbon markets and sustainability reporting standards across major economies including the European Union, the United States, India, and China. The report further evaluates how climate risks are transmitted into financial markets through regulatory transitions, physical climate risks, technological disruption, and information asymmetry.

Using a comparative and analytical research approach, the report studies the role of ESG disclosures, carbon pricing instruments, and disclosure transparency in shaping investor decision-making and asset pricing. The findings suggest that higher-quality climate disclosures reduce uncertainty and information asymmetry, thereby lowering the cost of capital and improving firm valuation.

The report also highlights the growing significance of carbon markets and climate-related financial regulations in promoting sustainable investment practices and facilitating the transition toward a low-carbon economy. Furthermore, it identifies key challenges including regulatory fragmentation, disclosure inconsistency, greenwashing concerns, and implementation barriers across jurisdictions.

Overall, the research concludes that climate disclosure has become a financially material component of modern financial systems and will continue to play a critical role in shaping global investment trends, corporate governance practices, and long-term economic sustainability. As financial markets increasingly integrate sustainability considerations into investment and valuation decisions, climate-related disclosures are emerging as an essential element of corporate financial reporting and risk assessment.

The study further highlights that transparent and standardized disclosure practices can strengthen investor confidence, improve market efficiency, and support informed capital allocation decisions.

The research further indicates that the future growth of sustainable finance will depend largely on stronger regulatory coordination, improved disclosure consistency, and greater corporate accountability. With the increasing global focus on net-zero targets and climate governance, businesses are expected to integrate climate risk management into their strategic and financial planning processes. This shift reflects the growing understanding that climate risks are capable of affecting profitability, operational stability, and long-term business performance across industries.

The report also demonstrates that climate-related financial regulations, ESG-focused investments, and carbon pricing mechanisms are gradually reshaping global capital markets. Investors and financial institutions are increasingly relying on climate-related information to evaluate business resilience, environmental performance, and exposure to transition risks. At the same time, challenges such as inconsistent reporting standards, regulatory fragmentation, and greenwashing concerns continue to limit the effectiveness and comparability of climate disclosures across markets.

The study ultimately highlights the growing significance of climate disclosure within modern financial and economic systems. As sustainability considerations become increasingly integrated into investment analysis, corporate governance, and regulatory frameworks, climate-related information is expected to play a more central role in shaping capital allocation and financial decision-making. The report further emphasizes that improvements in disclosure standards, reporting consistency, and sustainability frameworks may strengthen transparency and comparability across markets, while also supporting more effective assessment of climate-related risks, business resilience, and long-term economic performance.

INTRODUCTION

Section 1

INTRODUCTION

Climate Finance Context

The financial systems of today undergo structural changes because climate-related factors now receive increased recognition in financial systems. Climate change has evolved from its original status as an externality to become a significant element in financial risk assessment which determines investment returns and capital distribution. The transition process receives backing from multiple studies which show that climate-related data affects how companies determine their worth and how investors make decisions and how markets function.

Growing Importance of Climate Risk in Financial Systems

Recent academic literature confirms that climate risk operates as a financial risk which affects entire systems instead of being an issue that only affects individual companies. The empirical evidence demonstrates that climate-related shocks create effects which extend across multiple sectors and these effects disrupt credit markets and equity valuations and macro-financial stability. Sustainable finance research demonstrates that climate risk creates permanent risk which cannot be eliminated through investment portfolio diversification.

The financial models now include climate risk through increased required returns and risk premia. Financial models now include climate risk through increased required returns and risk premia.

he evidence from both industry and academic research demonstrates that ESG-related risks now show their effects through increased asset price volatility and valuation spread and through the long-term price behavior of assets.

The growing importance of climate risk exists because it affects future cash flow predictions and discount rates which serve as the foundation for financial valuation models. The analysis demonstrates that climate risk should be treated as a fundamental element of financial assessment because it affects financial evaluation results Climate risk now affects investment decisions, asset valuations, and market stability. Therefore, it has become an important factor in modern financial analysis and decision-making.

Integration of Climate Considerations into Financial Markets

Financial markets only started using climate information after a slow yet visible adoption process. Research shows that investors now use non-financial company information to evaluate both business risk and sustainability prospects.

- The expected returns will change according to the climate exposure assessment results.
- The company will direct its investments towards businesses that demonstrate superior environmental sustainability practices.
- The valuation models will now include climate-related risk factors as their core component.

Emergence of Climate Disclosure Frameworks and Carbon Pricing Mechanisms

Recent research by ScienceDirect (2024) shows that investors increasingly rely on non-financial information, such as ESG indicators, to evaluate both business risk and sustainability prospects. Similarly, studies published in Wiley Online Library highlight that sustainability disclosures play a significant role in shaping investment decisions and capital allocation

The expected returns will change according to the climate exposure assessment results.
The company will direct its investments towards businesses that demonstrate superior environmental sustainability practices.
The valuation models will now include climate-related risk factors as their core component.

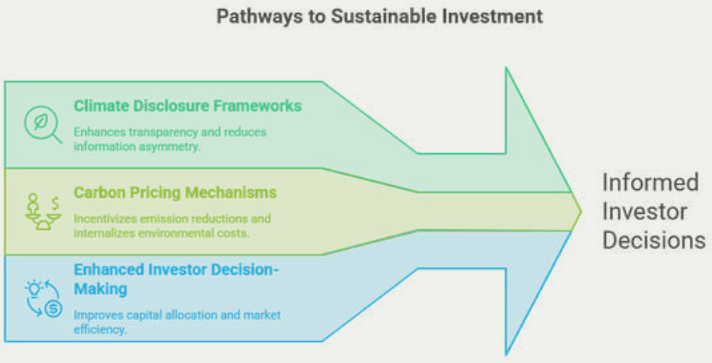
However, empirical evidence suggests that this integration remains incomplete and heterogeneous across markets. This heterogeneity arises due to differences in regulatory frameworks, varying ESG disclosure standards, and inconsistent data quality across firms and jurisdictions. As a result, investors face information asymmetry and difficulties in comparing climate-related risks across assets. This limits the accurate pricing of climate risk, as mispricing may occur due to underestimation or overestimation of risk premiums, thereby reducing market efficiency.
However, this integration remains uneven across markets due to differences in ESG standards, regulations, and data quality. As a result, investors face difficulties in assessing and pricing climate-related risks accurately.

Emergence of Climate Disclosure Frameworks and Carbon Pricing Mechanisms

The increasing popularity of **climate disclosure** frameworks together with carbon pricing systems exists because these instruments serve the purpose of **resolving financial market information imbalance problems**. To better understand the role of disclosure frameworks, insights from information economics provide a useful theoretical foundation. Information economics suggests that disclosure acts as a mechanism to **reduce information asymmetry between firms and investors**. In the context of ESG reporting, improved transparency helps investors **make more informed decisions** by lowering uncertainty regarding firms environmental and financial risks. The practice of ESG disclosure **enables capital markets to operate with less information asymmetry while achieving better transparency.**

The companies that maintain superior disclosure practices produce better results with their investor recognition and their valuation processes. Company behavior and market results are affected by both regulatory disclosure frameworks and voluntary disclosure systems according to research findings.

Research by Ioannou and Serafeim highlights that sustainability disclosures play an important role in improving transparency and reducing information asymmetry between firms and investors. By providing clearer information on environmental risks and long-term resilience, such disclosures enable investors to make more informed assessments of corporate performance and valuation. Similarly, carbon pricing mechanisms internalize the environmental costs of greenhouse gas emissions by assigning them a direct monetary value, encouraging firms to incorporate climate-related costs into their operational and investment decisions. Together, climate disclosure frameworks and carbon pricing mechanisms enhance investor decision-making, influence corporate behaviour, and contribute to more efficient capital allocation and market outcomes.



Role of Capital Markets and Financial Institutions in Climate Transition Financing

Financial markets exist to function as the main mechanism which **redistributes capital based on climate-related financial risks** and newly discovered investment opportunities. The research evidence establishes that companies with better sustainability practices achieve higher financial access while facing fewer limitations on their capital resources.

Cheng, Ioannou, and Serafeim conducted their groundbreaking research which demonstrates that companies with better CSR performance experience reduced financing restrictions because their agency costs decrease and their financial information becomes more transparent.

The recent research demonstrates that **ESG disclosure affects capital structure decisions** because it **enhances equity financing access** while creating impacts on debt and equity financing expenses.

The findings demonstrate that financial institutions function as more than mere financial intermediaries; their investment and lending practices enable them to shape both the speed and trajectory of climate transition.

Research Objectives & Scope

The growing intersection between climate disclosure and financial markets raises important questions regarding the role of information in shaping market outcomes. This study is positioned within this intersection, focusing on the economic implications of climate-related disclosure.
This study is positioned at the intersection of climate disclosure and financial markets, focusing on the economic impact of climate-related disclosures on market outcomes. It examines how disclosure practices influence investor decisions, corporate valuation, and overall market efficiency.

Core Research Questions on Climate Disclosure and Financial Markets

This research is guided by the following core questions:

1. Does climate-related disclosure **materially affect** financial market outcomes?
2. How does the quality of disclosure influence investor behaviour and asset pricing?
3. To what extent does disclosure reduce uncertainty in financial markets?

Hypotheses Linking Disclosure Quality and Cost of Capital

The study establishes its hypotheses through the empirical relationships which show how disclosure affects information asymmetry and the cost of capital.

A substantial body of research supports the following relationships:

1. The ESG disclosure process builds a transparent information framework which decreases asymmetrical knowledge distribution between parties and results in reduced risk assessment costs.
2. Companies that implement superior sustainability methods gain improved financial access while experiencing decreased restrictions on their capital expenditures.
3. Organizations that provide higher quality disclosure achieve lower expenses for both their equity and debt financing needs.

More recent empirical studies further confirm that firms with higher ESG disclosure scores exhibit lower cost of equity due to reduced perceived risk

Based on this, the study proposes the following three hypothesis:

H1: Higher-quality climate disclosure reduces the cost of capital

H2: Poor or inconsistent disclosure increases perceived risk and required returns

H3: Disclosure serves as a signalling mechanism affecting firm valuation

Geographic Scope (EU, US, India, China, Global Markets)

The research uses a cross-national approach to study differences in regulatory frameworks and market systems and disclosure methods.
Research demonstrates that ESG disclosure affects different regions because of their unique institutional systems and governance standards and market development levels.
The analysis improves its applicability by studying how disclosure practices function across different financial and regulatory frameworks in multiple regions which include the EU and US and India and China.

Timeframe of Analysis

The chosen time period from 2018 to 2025 marks a vital time for climate finance development because ESG investment has surged and disclosure requirements have expanded and regulatory bodies have intensified their enforcement activities.

The research shows that ESG disclosure effects develop through three distinct phases which begin with a capital cost reduction and continue through market responses to the latest information.

The research period enables the study to observe three different changes which include:

1. The evolution of disclosure practices from optional to mandatory structured systems.
2. Investors have begun to value climate risk, which increases their capability to assess climate-related financial risks.
3. Financial markets have started to adopt climate-related data, which they now use in their operations.

BACKGROUND & LITERATURE REVIEW

Section 2

BACKGROUND & LITERATURE REVIEW

Evolution of Climate Risk in Financial Economics

Systemic Financial Risk as Climate Risk

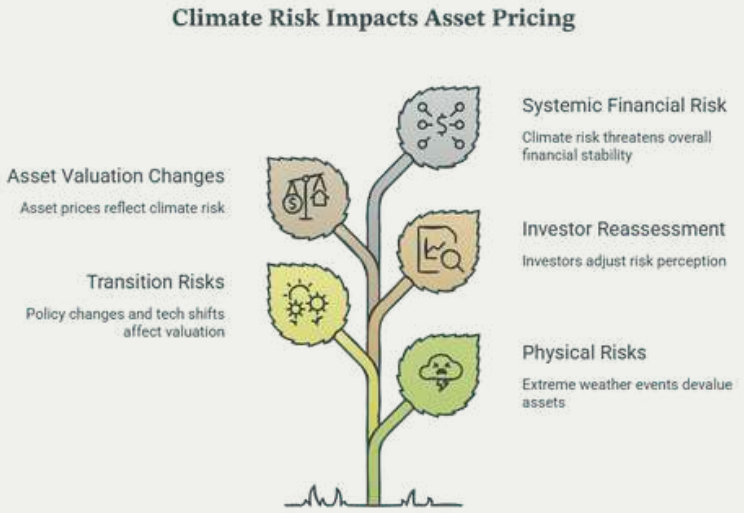
The issue of climate risk is now widely seen as a threat to financial and systemic risks. Major institutions have pointed out that conventional risk management models do not account for climate change impacts. For instance, the Bank for International Settlements (BIS) stresses that "conventional risk modeling techniques cannot sufficiently accommodate the extraordinary character of climate risks". In a similar vein, the International Monetary Fund (IMF) advises regulators to include climate risk in their regulatory activities, noting that "climate matters for the stability of financial systems" and that "systemic risks induced by climate risks need to be taken into consideration and mitigated".

Transition Risk vs. Physical Climate Risk

The climate risks are categorized as either physical risks or transition risks. The physical risks include the immediate consequences of climate events, such as loss arising out of floods, storms, heatwaves, or sea-level rise. Transition risks include the risks emanating due to the economic transformation necessary to mitigate climate change, for example, the cost incurred due to carbon pricing, stranded assets in the fossil fuel sector, or other changes due to the shift towards zero emissions. In effect, each of the risks is felt differently by various investors. For instance, banks have a relatively high exposure to physical risks through their mortgage or loan exposures tied to assets that are physically at risk, whereas equity investors can incur significant transition risks from equity investments in firms having a business model based on high carbon intensity.

Climate Risk Pricing in Asset Markets

Climate risk factors are now being priced in financial markets. There are studies with robust empirical evidence showing that there are indeed pricing consequences for both physical and transition risks, even though they are not conclusive. For instance, a study uses heat-stress differences across regions and establishes that firms in hotter regions incur a climate risk premium; their bonds yield relatively higher yields, particularly long-term bonds rated below investment



grade, while their stocks have higher expected returns. Investors are increasingly demanding higher returns for exposure to physical climate risks. Asset pricing studies indicate that green stocks, which are firms with lower emissions and cleaner technologies, have often outperformed their brown counterparts, particularly following the Paris Agreement.

Climate risks are also influencing the value of real assets. An ECB assessment found that commercial properties exposed to climate hazards such as floods have experienced increasing price discounts over time. Similarly, buildings with poor energy efficiency have faced liquidity constraints, suggesting that both physical and transition risks are progressively being incorporated into asset prices.

While researchers continue to debate the extent to which climate risk is fully priced into financial markets, there is broad consensus that it represents a material and systemic source of financial risk. Some studies identify a carbon premium, whereby firms with higher emissions face higher financing costs, whereas others find weaker evidence. Nevertheless, institutions such as the NGFS, BIS, ESRB, and IMF have developed frameworks highlighting how physical and transition risks affect financial institutions and market stability. Overall, the literature increasingly recognizes climate change as a cross-cutting financial risk with implications across sectors and asset classes.

Climate Disclosure Literature

ESG Disclosure and Cost of Capital

The literature on climate change and ESG disclosure has been expanding at an extremely rapid pace. There has emerged one important stream of inquiry in this regard that examines if firms' transparency with respect to climate issues can have any impact on their cost of capital/financing. The empirical findings on this front appear largely positive, meaning that enhanced disclosure related to environmental or ESG aspects reduces the cost of capital for firms by lowering the level of uncertainty. For example, a study in 2025 involving companies in the S&P 500 index found that more ESG disclosure is strongly linked with lower cost of capital, particularly the environmental and social parts of it. It was similar to Chava (2014), who discovered that firms emitting more in the U.S. needed higher returns on stocks to attract investors.

Climate Transparency and Decision-Making

It is also important to consider the effect of disclosure on investor decision-making. According to various surveys and industry publications, climate disclosure has become an important issue for the asset owner community.

For instance, the survey conducted in 2025 among over 220 investors, including asset managers and pension funds, discovered that 75% of respondents evaluate financial risk and opportunities associated with climate change in their investment portfolio, while a comparable number of investors have board-level oversight over their climate strategy. Simply put, investors require robust climate disclosure; they rely on emissions information, transition planning, and other sustainable development metrics when allocating their resources.

Financial Materiality vs Double Materiality

One such discussion revolves around materiality. In conventional finance, materiality involves whether the matter could potentially affect the value of the company to the investors, financial or “outside-in” materiality. The European Union has adopted a concept of double materiality, which looks at how the company affects the environment and society, known as impact or inside-out materiality. For purposes of EU regulations (CSRD/ESRS), matters that should be included in corporate reporting are considered material if one of the two approaches applies. This perspective provides a more holistic assessment of climate change impacts on businesses.
Nonetheless, the unique uncertainty associated with climate change poses a challenge.

Some scholars have pointed out that outcomes regarding climate change are highly uncertain since the possibilities are not reducible to probabilities.

Empirical Findings on the Quality of Disclosure and Market Efficiency

However, empirical investigations into the quality of corporate disclosures reveal conflicting results regarding market efficiency. Firstly, a number of studies indicate that financial markets are not always efficient with respect to the use of climate-related information.

Thus, Liesen et al. state that in the period from 2005 to 2009, U.S. investors gained abnormal gains of up to 13% per annum due to inefficient pricing of climate disclosure information on carbon emissions. According to the authors, "financial markets were inefficient in pricing publicly available information on carbon disclosure and performance," which means that more standardized disclosure can increase market efficiency. At the same time, there are those who consider adequate information disclosure an essential prerequisite for market efficiency.

On balance, the academic research seems to indicate that high-quality climate disclosures, by eliminating information asymmetry and potentially reducing financial costs, will be beneficial in theory; however, the present state of affairs in the marketplace is hampered by the newness of climate-related risks. In numerous instances, the price response to climate announcements is delayed or even partial. As observed in an article review, for instance, the literature on the topic is “incomplete and only tangentially addressing” the effect of disclosures on risk pricing. At the same time, mandatory climate-related disclosures are becoming increasingly common, such as those imposed under EU CSRD or SEC guidelines in the United States and ISSB standards.

THEORETICAL FRAMEWORK

Section 3

THEORETICAL FRAMEWORK

Climate Risk Transmission to Financial Markets

Regulatory and Policy Transition Risks

The impact of regulatory risks on valuation can be captured through the reduction of cash flows and an increase in discount rate. Simple scenario. If a firm earns ₹100 annually initially with stable expectations. Should there be a 20% rise in production costs owing to the carbon tax, the cash flows would be ₹80. The required return increases from, say, 10% to 13% at the same time because of uncertainty about future policies. The combined effect isn't linear but the company sees a 20% drop in earnings and a higher discounting factor; this reduces its value, particularly much more than linear. Regulatory risk is shown to enhance value loss via double-channel effect and financial market valuation impact is highly important.

Technological Transition and Industry Disruption

Valuation is impacted by technological disruption through a change in long-term growth expectations. For example, suppose a traditional energy company is expected to grow at 5% per year. If in the future, there is less demand due to renewable energy, then growth expectations may fall to 1-2% per year. Even if the current profits do not change, the valuation will decline, the reason is that the prices of assets depend on positive future growth. By contrast, firms adopting new technologies may see growth expectations ramp up to 8%- 10% and valuation multiples rise. The finding indicates that expected growth transitions are the main channels by which technological transition risk predominantly operates.

Physical climate risk from extreme weather events

Frameworks of expected loss can help analyse physical risk. Let there be a firm that has a 10 percent probability of facing a climate event causing ₹50 loss every year. Each year, the expected loss lowers expected cash flows by ₹5. However, the effect goes further than this expectation. The timing and magnitude of these shocks are uncertain, which generates volatility and investors want more return. To illustrate, a discount rate increase from 10% to 12% results in a valuation decline that is greater than the direct expected loss. This signals that physical risk functions harm expected returns and risk perception, amplifying their financial impact.

Litigation and liability risks related to climate impacts

Assessing litigation risks may be similar to assessing contingent liabilities. In case a firm has a 30% chance of receiving ₹200 legal compensation, then expected liability is ₹60.

This directly lowers the value of firms, but what really matters is the ambiguity around the resolution of lawsuits increases the perceived risk. Investors could potentially increase the discount rate to account for this uncertainty, decreasing valuation further. As a result, the litigation risk affects the financial markets not only by raising the expected costs but also by increasing risk premiums.

Information Economics of Climate Disclosure

Asymmetric information in climate risk reporting

When compared to investors, firms have more knowledge of their climate risk exposure. The differences in firms' climate-related risks make it difficult for investors to appropriately price assets. They are often unable to distinguish between the two.

The absence of a standard and mandatory disclosure framework assists firms in disclosing good information selectively while withholding bad information. This leads to adverse selection. When market inefficiencies arise and uncertainty increases, investors demand a higher return to compensate for the danger. As a result, firms with low transparency may burden a higher cost of capital.

Signaling theory and corporate sustainability disclosure

Signaling theory suggests that companies voluntarily disclose information about climate to distinguish themselves from one another. Firms use quality disclosures to communicate superior environmental performance and may not use non-credible disclosures.

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Signaling theory and corporate sustainability disclosure

Signaling theory suggests that companies voluntarily disclose information about climate to distinguish themselves from one another. Firms use quality disclosures to communicate superior environmental performance and may not use non-credible disclosures. Investing in such disclosures is costly to imitators. Therefore, they are credible signals to reduce asymmetry in information.

These signals are interpreted by investors as showing low long-term risk and good governance in a firm, leading to increase in valuation and fall in cost of financing. On the other hand, in case of poor or inconsistent disclosure, the firm is seen as risky.

Investor learning and market adjustment mechanisms

Climate data is complex and does not get reflected in financial markets immediately. So, the investors update their beliefs progressively through a learning process based on new information. This refers to Environmental Events, Regulatory Developments and Disclosures.

Theoretical models based on Bayesian learning show that markets can underreact when dealing with uncertain or ambiguous information. As time passes, as information accumulates, prices more fully adjust, sometimes resulting in sharp corrections. Climate risks tend to be underpriced in the short term but can cause considerable market price adjustments in the long term.

Conceptual model linking disclosure to risk repricing

Climate disclosure and asset pricing can be viewed through a valuation framework. In such a framework, the value or price of a firm depends on expected future cash flows. Further, it also depends on the discount rate. Climate disclosures impact both elements through shaping future risk assessments and changing views on uncertainty.

The mechanisms discussed above can be formally captured within a standard valuation framework.

$$V = \sum_{t=1}^{T} \frac{E(CF_t)}{(1 + r + \lambda climate)^t}$$

In this framework, the climate risk premium reflects extra uncertainty that comes with climate-exposure. Increased transparency reduces ambiguity, thus leading to lower premium resulting in higher valuations. On the other hand, poor or inconsistent disclosure raises uncertainty, increasing the cost of capital while decreasing firm value. Transparency is crucial in financial markets.

We now apply the valuation formula in a real scenario:

Assume:

- Expected cash flow (CF) = ₹100
- Base discount rate (r) = 10%

Case 1: Poor Climate Disclosure

- Climate risk premium (λ) = 5%
- Total discount rate = 15%

$$V = \frac{100}{1.15} = 86.96$$

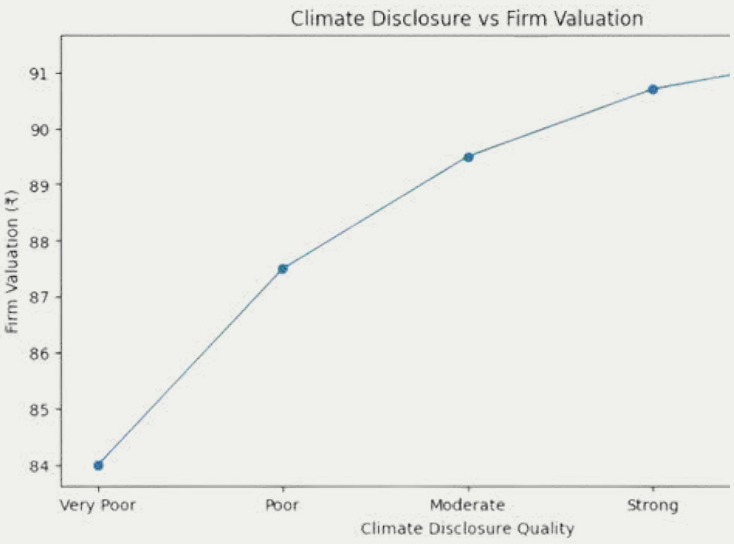
Case 2: Strong Climate Disclosure

- Climate risk premium (λ) = 2%
- Total discount rate = 12%

$$V = \frac{100}{1.12} = 86.29$$

Analysis:

The divergence in valuation of ₹86.96 and ₹89.29 has occurred merely because of the change in risk. Enhanced disclosure brings about a reduction in uncertainty, which results in a lower climate risk premium and a growth in firm value.



Consequently, climate disclosure has a measurable financial impact that directly affects valuation through the discount rate channel.

Carbon Pricing and Asset Valuation

Carbon pricing as a policy signal to markets

Carbon pricing mechanism includes carbon tax and emissions trading system's, they are considered important policy instruments that internalise the environmental cost of carbon emission. Unlike general regulatory risks discussed earlier, carbon pricing represents a direct and quantifiable policy instrument, allowing for more precise estimation of financial impact. Policies that put a price on emissions give firms a clear dollar incentive to cut their carbon footprints.

Theory states that carbon pricing is a type of Pigouvian tax that addresses market failures resulting from negative externalities. Financial markets see carbon pricing as a signal of regulatory future and they change the price of assets, mainly for highly intense firms.

Impact of carbon pricing on firm operating costs

Consider a company that earns ₹500 every year and incurs costs of ₹400, for a profit of ₹100. If carbon pricing increases costs by ₹50, profit reduces to ₹50 which is a 50 percent drop. Furthermore, when fat-tailed risks like unexpected sharp rises in the cost of carbon or changes in regulation become part of the risk scenario faced by investors, then the level of uncertainty will rise exponentially, which in turn causes a further rise in the discount rate and lowers firm value even more.

If one values the share price according to expected profits then firm value drops in the same proportion. Yet, if the investors also expect future carbon prices to rise by more, they will further increase the discount rate, leading to a bigger valuation drop. It shows that the implications of carbon pricing vary by profitability and expectation.

Stranded asset risk in carbon-intensive industries
Consider a coal plant expected to produce ₹100 every year for the next 20 years. If climate policies limit its usability to 10 years, half of its expected cash flows will be lost. Valuation is immediately revised downwards as no future earnings can ever be recovered. While temporary shocks are important, the stranding of assets signifies a structural and irreversible decline in value that is more interesting for investors.

Carbon cost pass-through and sectoral competitiveness

Assume costs for two firms increase by ₹20 because of carbon pricing.

- Firm A's full cost is passed on to consumers which results in profits remaining stable.
- Company B is unable to transfer the costs, which results in a decrease in profits.

In time, Firm A continues to maintain a steady value whereas Firm B sees a decline in its value. Capital flows into firms with pricing power. Carbon pricing does not just increase the cost for firms but changes the dynamics of competition such that the firms that have pricing power get capital.

EVOLUTION OF CLIMATE DISCLOSURE REGULATIONS

Section 4

EVOLUTION OF CLIMATE DISCLOSURE REGULATIONS

The period from 2018 to 2025 witnessed a fundamental transformation in how companies worldwide are expected to report climate-related risks and opportunities. What began as a fragmented landscape of voluntary frameworks has evolved into a complex, multi-layered system of mandatory and semi-mandatory regulations spanning the European Union, the United States, and over 35 other jurisdictions. This section examines the four primary pillars of this regulatory evolution: the TCFD framework, the ISSB's global sustainability standards, the EU's Corporate Sustainability Reporting Directive (CSRD), and the contested trajectory of the US SEC's climate disclosure rule.

Global Regulatory Landscape

Before exploring individual frameworks, it is important to understand the core problem each sought to solve. Before the late 2010s, climate-related disclosures across companies and jurisdictions were inconsistent, non-comparable, and largely voluntary. This created systemic challenges for investors, lenders, and regulators who needed clear, comparable data to price climate risk. The regulatory response unfolded in several overlapping waves, beginning with voluntary standard-setting in 2017, scaling to mandatory regional regulation by 2023, and extending toward a convergent global baseline by 2025.

TCFD Framework and Voluntary Disclosure Standards

Origins and Mandate

The Task Force on Climate-related Financial Disclosures (TCFD) was established by the Financial Stability Board (FSB) in December 2015 in response to growing concern about unpriced climate risk in global financial markets. The task force brought together representatives from banks, insurance companies, asset managers, pension funds, and credit rating agencies - the preparers and users of financial disclosures - to develop a common framework for climate-related reporting.

The TCFD released its final recommendations in June 2017, built around four core thematic areas:

Governance: The organization's governance around climate-related risks and opportunities.

Strategy: The actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.

Risk Management: The processes used to identify, assess, and manage climate-related risks.

Metrics and Targets: The metrics and targets used to assess and manage relevant climate-related risks and opportunities.

Growth and Adoption

Despite their voluntary nature, the TCFD recommendations rapidly gained traction. The number of companies disclosing TCFD-aligned information increased by 26% between 2017 and 2021. By October 2022, over 3,800 organizations had publicly declared support for the TCFD framework. By the time of the TCFD's final status report in 2023, that number had grown to nearly 5,000 organizations across 100+ countries, representing a combined market capitalization of $27 trillion.

Disbanding and Legacy

In October 2023, the TCFD fulfilled its remit and disbanded. The Financial Stability Board transferred monitoring responsibilities to the IFRS Foundation and its International Sustainability Standards Board (ISSB). This transition was not an ending but a formalization: the TCFD's four-pillar structure has been embedded into virtually every major subsequent regulation, from the EU's ESRS to the ISSB's IFRS S2 and the SEC's now-stayed climate rule.

ISSB Global Sustainability Reporting Standards

IFRS S1 and IFRS S2 - The Twin Standards

The International Sustainability Standards Board (ISSB) was announced at COP26 in Glasgow in November 2021 and formally established by the IFRS Foundation. Its mandate was to create a single, globally accepted baseline for sustainability and climate-related financial disclosures, effectively resolving the 'alphabet soup' of competing frameworks that had characterised the previous decade.

In June 2023, the ISSB issued its inaugural sustainability standards: IFRS S1 (General Requirements for Disclosure of Sustainability-related Financial Information) and IFRS S2 (Climate-related Disclosures). Both standards became effective for annual reporting periods beginning on or after January 1, 2024.

IFRS S2 builds directly on the TCFD's four-pillar framework and incorporates industry-specific disclosure metrics derived from the Sustainability Accounting Standards Board (SASB) standards. In December 2025, the ISSB issued amendments to greenhouse gas emissions disclosures under IFRS S2, aimed at reducing complexity and the risk of duplicative reporting during the implementation phase.

Global Adoption Trajectory

Adoption of the ISSB standards has accelerated rapidly. According to S&P Global's January 2026 Regulatory Tracker, as of January 1, 2026, 21 jurisdictions had adopted the standards on a voluntary or mandatory basis, with rules in Chile, Qatar, and Mexico becoming effective at the start of 2026. A further 16 jurisdictions were planning future adoption.

Notable developments include Australia issuing its Sustainability Reporting Standards (ASRS) in 2024, closely aligned with IFRS S1 and S2; Japan's Financial Services Agency proposing to mandate ISSB-aligned standards; and China's Ministry of Finance issuing a climate-related standard based on IFRS S2. The International Organization of Securities Commissions (IOSCO) endorsed the ISSB standards shortly after their June 2023 publication, signaling support for adoption across the 130 jurisdictions it represents.

ISSB vs. TCFD -Continuity and Enhancement

The ISSB's absorption of the TCFD's monitoring responsibilities in June 2024 formalized what was already a deep conceptual alignment. Both share the governance, strategy, risk management, and metrics structure. The primary differences are scope and legal weight: the ISSB standards are designed to be jurisdictionally adoptable as binding law, while TCFD was always advisory. IFRS S2 does not require companies to have a climate transition plan but does require material disclosure of how they are managing both physical and transition climate risks.

EU Corporate Sustainability Reporting Directive (CSRD)

Scope and Structure

The European Union's Corporate Sustainability Reporting Directive represents the most comprehensive mandatory climate and sustainability disclosure regime in the world as of 2025. It entered into force on January 5, 2023, replacing the earlier Non-Financial Reporting Directive (NFRD).

The CSRD is estimated to affect more than 50,000 companies in Europe and over 10,000 non-European companies - more than triple the number covered by the NFRD. US parent companies with EU subsidiaries exceeding certain size thresholds are also in scope, required to report by 2029 on FY2028 operations at a consolidated level. Companies subject to the CSRD must report according to the European Sustainability Reporting Standards (ESRS), a set of 12 sector-agnostic standards developed by EFRAG (European Financial Reporting Advisory Group) and adopted by the European Commission in July 2023.

The Double Materiality Principle - The CSRD's Defining Feature

The central innovation of the CSRD-and its key distinction from TCFD and ISSB frameworks is the concept of 'double materiality.' While investor-focused frameworks like ISSB use 'single materiality' (only reporting what is financially material to the company), the CSRD requires both:

1. **Financial materiality**: How do sustainability factors affect the company's financial performance and position?
2. **Impact materiality**: How does the company affect people and the environment through its operations, value chain, products, and services?

This dual requirement dramatically expands the universe of disclosures required compared to investor-only frameworks and makes the CSRD the most demanding climate reporting regulation globally.

Phase-In Timeline and the Omnibus Simplification
Wave 1 companies (large EU entities previously subject to the NFRD) began reporting under the CSRD for FY2024, publishing their first reports in 2025. However, the scope of the CSRD was significantly revised by the EU Parliament's approval of the Omnibus I simplification package in December 2025.

US SEC Climate Disclosure Proposals

The Road to the 2024 Final Rule

The United States presents a study in regulatory ambition meeting political and legal resistance. The SEC's efforts to establish mandatory federal climate disclosure rules became one of the defining regulatory controversies of the early 2020s. Investor demand for standardized climate disclosure from the SEC dates back to at least 2003. On March 6, 2024, the Commission adopted final climate disclosure rules in a historic 3-2 vote.

The Final Rule would have required domestic and foreign registrants to include extensive climate-related information in their registration statements and periodic reports, including material climate-related risks, governance disclosures, scenario analysis, and, for large accelerated filers, Scope 1 and 2 greenhouse gas emissions if material.

Legal Challenges and Withdrawal

The rules faced immediate and overwhelming legal challenge. Industry groups, state attorneys general, and NGOs challenged the rule from multiple directions. Litigation was consolidated in the US Court of Appeals for the Eighth Circuit under Iowa v. SEC (No. 24-1522). On April 4, 2024- less than a month after adoption - the SEC issued a voluntary stay of the rules pending judicial review. Under the Trump administration, the SEC voted in March 2025 to stop defending the rules. The rules have never gone into effect.

Sub-National Action: California Fills the Federal Gap

With the federal mandate effectively neutralized, sub-national regulation has stepped into the void. California passed two landmark climate disclosure laws in October 2023: SB-253 (Climate Corporate Data Accountability Act), requiring Scope 1 and 2 emissions reporting from August 2026 and Scope 3 from 2027 for large companies doing business in California; and SB-261, requiring climate-related financial risk disclosure. California's Air Resources Board (CARB) confirmed in November 2025 that companies may use IFRS S2 as a framework for compliance. Illinois and Colorado also introduced their own emissions-disclosure legislation in early 2025.

Regulatory Drivers

The rapid evolution from voluntary frameworks to mandatory regulations across multiple jurisdictions was driven by a convergence of forces: financial stability concerns, investor demand, international climate commitments, and the explosive growth of ESG investing.

Financial Stability Concerns Among Regulators

The primary institutional catalyst for climate disclosure regulation was the reframing of climate change from an environmental concern to a systemic financial risk. The Network for Greening the Financial System (NGFS) - a coalition of central banks and supervisors founded in 2017 - was pivotal in this shift. By 2019, the NGFS, representing 72 central banks and supervisors, was explicitly encouraging companies to disclose climate risks in line with TCFD.

Regulatory responses to greenwashing risk, such as the EU's Sustainable Finance Disclosure Regulation (SFDR) and related taxonomy regulations, further reinforced demand for standardized corporate-level climate disclosure. The ISSB drew on the work of multiple preceding ESG frameworks, TCFD, the Climate Disclosure Standards Board (CDSB), the Value Reporting Foundation's Integrated Reporting Framework, and SASB Standards, effectively consolidating the ESG disclosure landscape into a single coherent standard.

CARBON MARKETS STRUCTURE & EVOLUTION

Section 5

CARBON MARKETS STRUCTURE & EVOLUTION

Introduction to Carbon Markets

Definition

A carbon market is a trading system where carbon credits or carbon permits are usually bought or sold. One credit stands for one metric tonne of carbon dioxide equivalent, often written as tCO_2e in short. The main aim of carbon markets is to put a price on emissions so that polluting becomes more expensive. In simpler words, if a company emits greenhouse gases, it has two choices. The company is either required to cut its own emissions, or it should buy extra permits from someone who has them to spare. That way, there is a financial push to reduce pollution and meet environmental rules.

Carbon markets are generally of two types. There are compliance markets, which are mandatory and run by governments and there are voluntary markets, which are optional and driven by companies' own climate promises. All these things will be covered in detail in the upcoming sections.

Objectives

Beyond making pollution more expensive, carbon markets aim to do more things. The first one is keeping costs low. Not every company can cut emissions at the same price. For example, a cement plant might reduce pollution cheaply by switching to a different fuel, while an airline, on the other hand, has few options and finds it expensive. Carbon markets let the cheap reductions happen first, and those companies cut their own emissions and sell their extra permits. The companies which find it expensive to reduce pollution simply buy permits instead. This way, the overall cost of meeting a country's climate target stays as low as possible. Another goal is pushing companies to innovate. When a carbon price is in place and is expected to stay or rise, businesses have a strong reason to invest in cleaner technology. A firm that develops a cheaper way to reduce emissions can not only comply for less money but also sell its unused permits to others. Over time, this drives technological progress across the whole economy. Carbon markets also raise money. In 2024, compliance markets generated over $100 billion for the second year in a row. Most of that goes back into climate projects, renewable energy, and help for low-income households who struggle with higher energy bills. They also try to stop carbon leakage which occurs when companies move their factories to countries with no carbon price just to avoid paying. Border carbon adjustments help by charging the same cost on imported goods, so moving away no longer saves money. Finally, there are side benefits. Less burning of fossil fuels means cleaner air and better health. Social funds like the EU's Climate Fund or Canada's household rebates help make sure poor communities are not hurt unfairly by rising energy prices. When you put all of this together, carbon markets are designed to do one big thing: maximise overall economic efficiency.

They create a single carbon price across the entire economy. Every company, every sector, faces the same cost for each tonne of CO_2.

That means reductions happen automatically where they are cheapest and not because a regulator decides, but because the market finds the lowest cost. The result is the biggest possible environmental benefit for every rupee, dollar or euro spent. That is the real point of the whole system.

Role in Climate Policy

Carbon markets are an important aspect of modern climate policy, serving as an alternative to the conventional regulatory approach based on market mechanisms. Rather than setting identical emission reduction targets, carbon markets make use of prices to impact behavior, allowing organizations to figure out their most efficient way of meeting their targets. Their importance cannot be underestimated in international climate policy, especially within the framework of the UNFCCC and the Paris Agreement, where countries are advised to rely on the mechanism of carbon trade to achieve their emission reduction targets. This mechanism helps reconcile the two aspects of climate policy: environmental benefits and economic efficiency thus allowing countries to take advantage of both for achieving their targets. Carbon markets may be viewed as a recent phenomenon that became an important aspect of climate policy, although the process of their emergence involved much time and many attempts of various policies and international actions. In the coming years, their importance may only increase as more nations adopt the practice of carbon pricing and international trading.

Evolution of Carbon Markets

Before moving forward let us first understand how the concept of carbon markets came into existence. This poses an important step in understanding the timeline and

Early Development (Pre-Kyoto)

The theory of pollution permit trading was formulated in the 1960s. According to Coase (1960) and Dales (1968), by capping emissions and allowing their trading, environmental issues could be addressed more efficiently compared to the traditional approach of regulation. The proof of cost-effectiveness was mathematically established by Montgomery in the early 1970s.

First actual implementations were made in the US. A lead credit trading scheme implemented in the 1980s saved about $250 million annually. In 1990, the Acid Rain Program was created as part of Clean Air Act Amendments, establishing the first-ever large-scale cap-and-trade system focused on sulfur dioxide (SO_2) emissions. From 1990 to 2007, there was a decrease of 43 percent in emissions, the goal was achieved three years ahead of schedule, and the costs turned out to be four times lower than initially estimated.

Such achievements contributed to the development of early climate policies. The first carbon taxes appeared in 1990 in Finland. In 2002, a national voluntary carbon market was established in the UK. All of the above served as an impetus for the creation of the Kyoto Protocol, the first international treaty with legal obligations concerning carbon trading.

Kyoto Protocol Mechanisms

The Kyoto Protocol was an important milestone as it was the first time that the international community entered into a legally binding agreement to cut emissions in the developed nations (Annex I countries). The Kyoto Protocol used three mechanisms of flexibility:

1. **International Emissions Trading (IET)**: The country that met its emissions reduction target could then sell its surplus "Assigned Amount Units (AAUs)" to another Annex I country that was struggling to meet its target, thereby establishing an emissions allowance market internationally.
2. **Joint Implementation (JI)**: Under this mechanism, Annex I countries could jointly participate in reducing emissions through a partnership where one of the participating countries would get emissions reduction units (ERUs), aiding both countries in reaching their target.
3. **Clean Development Mechanism (CDM)**: This is the most important out of all the three mechanisms, and under this, Annex I countries were able to make investment in reducing emissions in the developing countries and got certified emissions reductions (CERs). CDM has brought about $100 billion worth of investment in the low carbon economy by 2020.

In response to Kyoto, in 2005, the European Union established the EU Emissions Trading Scheme (EU ETS). This scheme has been termed the first mandatory multi-national carbon market and it still stands out as the biggest one.

The introduction of carbon pricing by the time EU ETS came into being was still very minimal at just 5 percent of the total global carbon emissions. While there have been some challenges in the operation of the EU ETS scheme, for example, too much allowance of carbon credits leading to a crash in prices, the scheme has shown how carbon trading could be done on a large scale. In 2025, 38 emissions trading schemes were active all over the world representing 19% of global emissions.

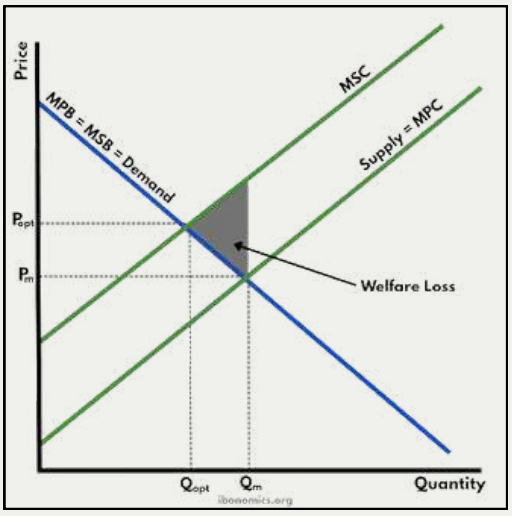
Post Paris Mechanism

The Paris Agreement of 2015 adopted a bottom-up approach, with each country determining its own climate objectives. The carbon markets mechanism was included in Article 6, but the implementation details were finalized only after nearly ten years of negotiations. In late 2024 at COP29, the parties reached an agreement on implementing rules. According to Article 6.2, ITMOs can be traded bilaterally. Article 6.4 establishes a UN-supervised Paris Crediting Mechanism (PACM) that replaces the CDM. By 2025, eighty-five nations had entered into authorisation agreements for Article 6. A rapid growth in carbon markets is observed. The Chinese ETS was introduced in 2021 and extended to cover the cement, steel, and aluminium sectors in 2025. This increased its scope by about 3 billion tons of CO_2e. In 2026, the definitive phase of the EU's CBAM starts. The ICVCM endorsed seven crediting programs according to the Core Carbon Principles. By 2025, there were thirty-eight ETSs operating globally, representing around 19% of global emissions, with an additional twenty ETSs under construction. Taken together, carbon pricing now covers approximately 28% of global emissions compared to only 5% in 2005.

Economic Foundation of Carbon Markets

Negative Externality

At the heart of carbon trading, there is the concept of a negative externality, whereby economic actions create unintended costs that have an impact on other parties who do not necessarily benefit from them. In relation to climate change, the producer emits greenhouse gases during production. This has led to climate change, health problems, and even environmental degradation. Nevertheless, the cost of production in this instance does not fall on the producer but rather the whole of society. This brings about one of the major issues associated with carbon trading. The cost of producing carbon goods for the company is lower than the cost of doing so for society. In this regard, there is an oversupply of these products in the market. For instance, using coal energy to produce electricity is cheaper than utilizing renewables since the latter comes at an additional cost to the economy. Graphically, the PMC is lower than the SMC.This gap between private and social cost leads directly to market failure.



Market Failure

The problem of global warming is seen as a classic case of market failure, which does not achieve social efficiency. This is attributable to several problems. First, the problem is based on the lack of pricing of carbon emissions; thus, it is easy to emit carbon dioxide, thereby producing excessive amounts of CO2 emissions. Second, climate stability can be regarded as a pure public good in that it is non-excludable and non-rival. Therefore, people cannot be denied access to the climate stability services, while its consumption by another individual does not affect anyone else. Consequently, the problem of free riders emerges, in which people want the service, but none pays for it. Besides, information asymmetry occurs, causing a lack of knowledge among consumers regarding environmental concerns. As shown in figure, the gap between private and social cost leads to overproduction (Q_m > Q_opt). This gap between private and social outcomes is the definition of market failure.

Role of Carbon Pricing

The economic instrument for internalising the negative externality associated with CO_2 emissions is carbon pricing. The concept can be attributed to economist Arthur Cecil Pigou, who suggested that a tax ought to correspond to the social cost associated with detrimental acts. When applying carbon pricing to the issue of global warming, the social cost becomes a price tag attached to each unit of carbon emitted by companies.

The result of carbon pricing is that companies begin to pay for their carbon emissions, thus addressing the market failure discussed above since the private cost becomes equal to the social cost, excess production of products that cause excessive emission of carbon is curtailed, and resource allocation becomes effective. The same applies to carbon pricing regardless of the form it takes. After discussing the economic reason behind carbon pricing, the next section addresses the major tools used in implementing carbon pricing policies.

Carbon Pricing Instruments

Governments use two main instruments to put a price on carbon: carbon taxes and cap-and-trade systems (also called emissions trading systems, or ETS). Both aim to make polluters pay, but they work differently and offer different kinds of certainty.

Carbon Tax

This is a tax set at a specified cost per ton of CO2 emissions. It is levied by the government, and firms must pay taxes according to their volume of emission. Since the tax rate is fixed, there is no uncertainty in terms of the cost of carbon emissions. The benefit of using a carbon tax is that it creates incentive for behavioral changes. Firms tend to opt for clean production processes, while consumers prefer to consume green products because carbon-intensive goods will be expensive. A further advantage is that the government will earn stable revenues from the carbon taxes, which could help them invest in climate mitigation measures and renewable energy production.

Carbon taxes have some disadvantages as well. First, there is no assurance that the set rate of reduction would be achieved since firms could choose to continue emitting carbon without adjusting their operations. Second, a carbon tax could meet political opposition as it increases the cost of doing business.

Examples: Sweden (more than €120 per tonne); Canada (backstop levy starting from €50 per tonne).

Cap-and-Trade Mechanism (Emissions Trading System)

In a cap-and-trade scheme, there is a definite limit on emissions in sectors subject to regulation. The authorities allocate or auction permits, each allowing one tonne of CO2 emissions. All firms need to surrender sufficient permits to match their emissions levels. The unique aspect is the possibility of trading. Firms with lower costs for reducing emissions do so, and then they sell their extra permits. Those with higher costs buy permits rather than incur high costs of reduction. The principal benefit is guaranteed emissions: there will be an upper limit on emissions, which can be reduced over time. However, the price of permits is uncertain because it is set by market conditions of demand and supply. An effective scheme has stability measures, such as a market stability reserve, to avoid wild fluctuations in prices. Examples: EU ETS (introduced in 2005, prices approx. €75-80 per tonne), China ETS (introduced in 2021, prices less than €15 per tonne). By 2025, 38 ETS were in operation globally.

Types of Carbon Markets

Feature	Compliance Carbon Market (ETS)	Voluntary Carbon Market (VCM)
Participation	Mandatory for regulated entities (e.g., power,	Voluntary, open to any organisation or
Governance	Government-regulated with legal enforcement	Private standards & registries
Primary Instrument	Allowances (permits to emit 1 tCO_2e)	Carbon credits (certified emission
Environmental Certainty	High: the cap guarantees a fixed emission limit	Low: depends on project quality &
Price Certainty	Low: allowance price fluctuates with market	Variable: high-integrity credits command
Primary Driver	Legal obligations & national climate targets	CSR, net-zero pledges, reputation, brand
Typical Price (2025)	€15 to €85 per tonne (EU ETS: €75 to €85)	$5 to $15 per tonne; premium credits
Market Size (2025 est.)	$1.5 trillion (global ETS)	$2.1 billion to $15.8 billion (estimates
Annual Volume (2025)	Not applicable (allowances, not credits)	200 million tCO_2e (202 $MtCO_2e$) retired
Coverage	38 ETS operational, covering 19% of global	Global; credits used by entities
Project/Asset Type	Allowances (government-issued, no underlying	Project-based (reforestation,
Integrity Standards	Government MRV, independent verifiers	ICVCM Core Carbon Principles
Growth Trend	Steady expansion: 20 new systems in	Rapid: projected to reach $9.9–$120B by

Institutional and Regulatory Framework

Reliable institutions and regulations are prerequisites for the functioning of the carbon market. This section will focus on the international institutions participating in the regulation of carbon markets, national regulations, and monitoring, reporting, and verification.

International Governance

The international carbon markets are regulated within the framework of the UNFCCC and its agreements, the Kyoto Protocol, and the Paris Agreement. The Kyoto Protocol introduced the mechanisms for climate change mitigation, such as the Clean Development Mechanism (CDM), whereas Article 6 of the Paris Agreement introduced two mechanisms governing the current international carbon markets, including Article 6.2 and Article 6.4. Specifically, the first mechanism relates to cooperation between countries, while the second concerns a carbon crediting scheme managed by the UN. Regarding the voluntary carbon markets, the Integrity Council for the Voluntary Carbon Market (ICVCM) established the Core Carbon Principles (CCPs) defining the quality standards of carbon credits at an international level. As of 2025, seven carbon crediting schemes and 36 methodologies have been approved by the ICVCM. Also, there are other international organizations operating in the same domain – IOSCO.

National Regulatory System

Every compliance carbon market follows its own national and regional rules and regulations. For instance, the European Commission supervises the EU ETS, which is the largest carbon market globally. The China national ETS is overseen by China's Ministry of Ecology and Environment. In the US, the California Air Resources Board supervises the California cap-and-trade program, while the Regional Greenhouse Gas Initiative involves ten states from the northeastern US. Some other examples of ETS include the UK ETS Authority in the UK, Environmental Protection Authority in New Zealand, and the Ministry of Environment in South Korea. Some of the upcoming carbon markets include those in Brazil, India, Indonesia, Turkey, and Vietnam.

Monitoring, Reporting, and Verification (MRV)

MRV forms the basis for the reliability of the carbon trading system. It confirms that the reduction is both real and measurable.

Monitoring: Ongoing measurement of emissions from the source point (such as power plants or industrial facilities) via standard measurement techniques.

Reporting: Reporting is done by organizations on their emissions and allowance balances to regulatory agencies or third parties.

Verification: The third-party auditor validates the reported information and adherence to regulations.

For voluntary markets, registries such as Verra and Gold Standard carry out the same functions in terms of verification. Another evolving approach is Digital Monitoring, Reporting, and Verification (DMRV).

Climate Disclosure Transmission

Section 6

CLIMATE DISCLOSURE TRANSMISSION

Equity Market Transmission Mechanisms

The transmission into financial markets of climate disclosures takes place mainly through equities markets, where the growing practice of disclosure and regulation means that such information is viewed as financially relevant, resulting in revisions of the expected firm value, risk, and performance. The mechanisms for how climate disclosures impact market results are outlined below.

Stock Market Reactions to Climate Disclosures

Climate disclosure brings new information about a firm's physical and transition risks, where this information impacts cash flow expectations, especially in light of regulatory costs, disruption, and possible stranded asset issues, whereas the risk of climate change itself increases the cost of capital (required rate of return).

This means that changes to both cash flows and discount rates mean a revision to the firm's stock price, whereby firms facing downside risks in their disclosures will react negatively to this, while other firms with credible and strategic transition disclosures might react positively or neutrally.

Sectoral repricing in carbon-intensive industries

However, the distribution of climate-related risks among the various industries is not uniform. Carbon-intensive industries like energy and utilities as well as heavy industries have been identified as facing relatively high transition risks in terms of carbon prices and regulations, as well as disruption to technology.

As the risks associated with climate become more evident via the process of disclosure, investor expectations about profitability and growth will be adjusted.

It follows that there will be a relatively different repricing among the different sectors, whereby carbon-intensive companies' valuations will be depressed while the the prospects for low-carbon/sustainable firms will be enhanced.

Investor Portfolio Reallocation

The increasing amount and quality of climate-related information also have implications for capital allocation decisions. Institutional investors, especially those with an ESG mandate, usually prefer companies with better climate performance and more quality disclosures. Good-quality disclosures lower information asymmetry and help build trust, while low-quality disclosures raise perceptions of risk.

Thus, there is an increased trend towards allocating capital to companies that are more prepared for the transition to a greener economy. This leads to a divergence in capital allocations, which accentuates valuation discrepancies between companies and industries.

Climate risk integration into equity valuation models

Factors related to the climate change issue are becoming part of equity valuation via effects on both cash flow expectations and the discount rate. Climate risks may result in an adverse effect on cash flow expectations by increasing operational expenses, fines or penalties due to regulations, or decreased demand for carbon-based products. Uncertainty associated with climate risks also results in an increased required return on equity because investors expect to earn higher rewards for taking the risk.

On the other hand, companies that practice climate disclosure have lower risk perceptions and growth expectations. These factors translate to lower required returns and higher company valuations. This is how climate disclosure helps set the cost of equity and influence overall firm value.

Market Reactions to Climate Regulation

Financial market responses to climate regulation have become an important factor, determining not only asset prices but also capital allocation decisions and business strategies. In contrast to the slow and continuous evolution of economic factors, regulatory policies such as carbon pricing, mandatory disclosure, and emission reduction goals are often implemented abruptly, acting as information shocks to the market.

From a financial viewpoint, the effects of climate regulation on the markets can be categorized into three main categories:
(1) Information shock;
(2) Cost transfer; and
(3) Risk adjustment.
This section examines these effects based on several empirical methods commonly employed in finance.

Stock Market Reactions to Climate Disclosures

High frequency event studies can be used for evaluating how markets react to announcements related to regulatory actions concerning climate change. Event studies focus on abnormal stock returns in relation to particular events, such as disclosure requirements or emissions goals.

Empirically, markets are seen to have an asymmetric reaction depending on exposure. Thus, after TCFD disclosure recommendations were adopted, firms with high carbon exposure saw negative abnormal returns, whereas those with high ESG positioning showed neutral or positive abnormal returns. Therefore, disclosures help to sort firms based on climate risk.

Another prominent example was the Paris Agreement of 2015. There is evidence of declines in stock prices of fossil fuel companies due to changed expectations about stricter regulation in the future. At the same time, positive abnormal returns for renewable energy firms have been noted.

Analytically, event studies show that climate regulation becomes incorporated into prices fast, which is in line with the semi-strong market efficiency assumption. Nevertheless, the size of the reaction is affected by previous expectations as well as by information asymmetry, implying stronger reactions to unexpected announcements.

Difference-in-difference analysis of regulatory changes

By means of difference-in-difference (DiD) analysis, it becomes possible to conduct an empirical test for the structural impact of climate regulation on affected firms compared to their unregulated counterparts across time.
One of the best examples of such an approach is a comparison of the European Union Emissions Trading System (EU ETS), according to which firms under regulatory pressure have higher compliance costs than unregulated companies, making them less profitable in the short term.

Yet, gradually, only efficient firms were able to overcome initial problems by using new technologies and reducing their emissions.
A similar situation can be observed for companies under carbon tax regulations in Sweden or Canada, where operating margins declined at first for those businesses but, in the end, depended on how well the companies innovated or passed the increased costs to customers.
What follows from such studies, the impact of climate regulation on the overall business performance does not result in losses for all firms but rather leads to heterogeneous results, implying that:

- in case of inefficient, carbon-intensive firms there are permanent losses
- in the case of adaptive firms they are able to recover or even get an advantage

In other words, regulation serves as a market selection mechanism.

Effects on cost of capital and equity risk premiums

The issue of climate regulation affects the cost of capital through the perception of risk. The high level of carbon emission poses risk since such companies are prone to high levels of regulation uncertainty and the risk of having stranded assets and future compliance costs.

Studies have shown that companies with high risk of exposure tend to exhibit higher equity risks premiums which mean that there is an increase in returns demanded by investors.
This translates to low stock prices and higher expected returns. It is evident that firms emitting greater levels of carbon tend to be more expensive to finance and valued relatively lower especially after important regulatory signals in U.S. market.

On the other hand, companies with environmental performance benefits from "green premium" whereby investors are willing to earn lower returns on their investments since the firms pose low risk levels. A good example to illustrate this point is in the coal industry compared to renewable energy firms.

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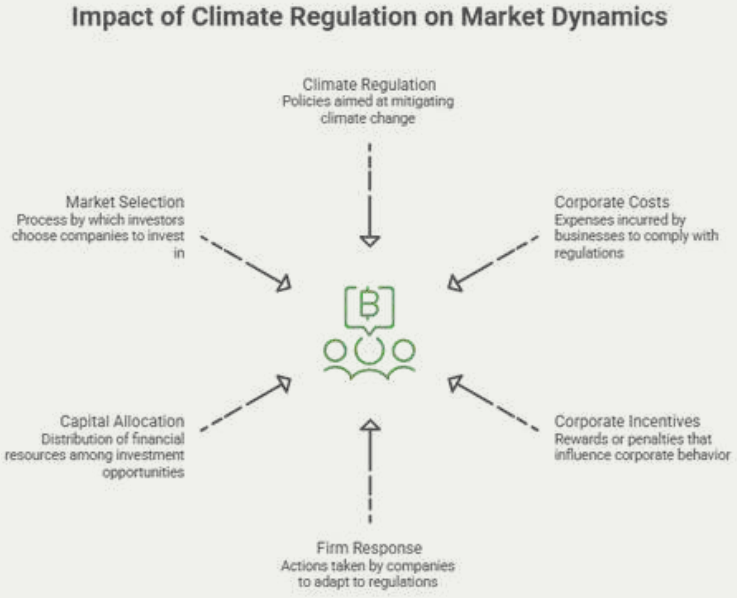

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Impact on corporate financing decisions

Climate regulation also impacts corporate capital structure decisions and funding mechanisms. As pressure increases from regulators, firms change their financing policies to cope with risks and retain the trust of investors.

Green finance products, including green bonds and sustainability linked loans, become popular among corporations that need funding to align themselves with environmental objectives. Corporations that establish emission reduction goals can borrow at a cheaper rate due to the use of sustainability linked finance instruments.

In parallel with the emergence of green financing, carbon heavy industries are facing stricter funding criteria from financiers. Banks are limiting their involvement in lending to high emission corporations while asset managers reduce fossil fuel corporation stocks. The global divestment trend shows that banks, asset managers, and other financial institutions are avoiding financing carbon intensive businesses.

Furthermore, companies that want to stay competitive start allocating their capital into low carbon projects due to the market expectation that in the future the profitability will depend on sustainability.

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Corporate finance is impacted by climate regulations through:

- differential cost of capital
- restraints on capital access
- capital reallocations

These factors facilitate the transition to a low carbon economy and reflect its dynamics through financial markets.

Conceptual Link to Financial Outcomes

The processes described above show clearly how disclosure of climate-related matters is translated into the capital market. Informational asymmetry is influenced by disclosure, which affects investors' perception of risks and returns on investments. This leads to changes in expected cash flows and discount rates that result in firm value determination and cost of capital.

With good and quality disclosure, it can be expected that there will be no uncertainty for companies as well as higher investors' confidence, translating into lower costs of capital. On the other hand, companies that have bad and insufficient disclosure can expect higher risks of failure that translate into higher costs of capital.

METHODOLOGY FOR ANALYSING MARKET IMPACTS

Section 7

METHODOLOGY FOR ANALYSING MARKET IMPACTS

This section explains the methods used to study how climate-related disclosures affect financial markets. It covers two main quantitative approaches and four key financial variables that are across the analysis.

Quantitative Methods

Two main quantitative methods are used in this study: **panel regression analysis** for understanding long-term trends, and **event study methodology** for measuring short-term market reactions to specific events.

Panel Regression Models for Long-Term Financial Analysis

The main method used to understand how the quality of a company's climate disclosure affects its financial outcomes over time is called panel regression analysis.
Unlike a simple snapshot analysis that looks at data from just one year, panel data tracks the same group of companies over several years. This is important because it lets us account for company-specific factors - like the quality of management, the type of business, or the industry - that don't change much over time but could otherwise distort our results if not controlled for.

The approach used here is called the fixed effects model, which is the standard choice for this type of research. It works by separating the effect of climate disclosure from everything else that makes one company different from another.

What Are We Measuring?

This study runs two separate regression equations - one for each dependent variable (the outcome we are trying to explain):

- **Equation 1 measures the Cost of Equity - the return that equity investors demand for putting money into a company.**
- **Equation 2 measures the Cost of Debt - the extra interest a company pays on its bonds, above a risk-free benchmark rate.**

Equation 1 Cost of Equity [Dependent Variable]

Cost of Equity is the dependent variable - it is what we are trying to explain and predict.

Equation (1)

$$
\begin{aligned}
Y(CoE)_{it} &= \beta_0 \\
&+ \beta_1 \cdot X(CDS)_{it} && = \text{Climate Disclosure Score} && (-) \\
&+ \beta_2 \cdot X(CRE)_{it} && = \text{Carbon Risk Exposure} && (+) \\
&+ \beta_3 \cdot Z(SIZE)_{it} && = \text{Firm Size} && (-) \\
&+ \beta_4 \cdot Z(LEV)_{it} && = \text{Leverage} && (+) \\
&+ \beta_5 \cdot Z(PROF)_{it} && = \text{Profitability} && (-) \\
&+ \beta_6 \cdot Z(BM)_{it} && = \text{Market Beta} && (+) \\
&+ \alpha_t && = \text{Firm Fixed Effects} \\
&+ \gamma_t && = \text{Year Fixed Effects} \\
&+ \varepsilon_{it} && = \text{Error Term}
\end{aligned}
$$

Symbol	Variable / Term	Expected Effect on Cost of Equity
$Y(CoE)_{it}$	Cost of Equity	Dependent Variable
$X(CDS)_{it}$	Climate Disclosure Score	(–) Decreases
$X(CRE)_{it}$	Carbon Risk Exposure	(+) Increases
$Z(SIZE)_{it}$	Firm Size	(–) Decreases
$Z(LEV)_{it}$	Leverage	(+) Increases
$Z(PROF)_{it}$	Profitability	(–) Decreases
$Z(BM)_{it}$	Market Beta	(+) Increases
α_t	Firm Fixed Effects	Control for time-invariant firm characteristics
γ_t	Year Fixed Effects	Control for common shocks across years
ε_{it}	Error Term	Idiosyncratic error

Where i = individual firm, t = year, and (+) / (–) show whether that variable pushes the cost of equity up or down.

Equation 2 Cost of Debt [Dependent Variable]

Cost of Debt is the dependent variable it is what we are trying to explain and predict.

Equation (2)

$$
\begin{aligned}
Y(CoD)] &= B0 \\
&+ B1 \cdot X(CDS)[it] \ (-) && \text{Climate Disclosure Score} && (-) \\
&+ B2 \cdot X(CRE)[it] \ (+) && \text{Carbon Risk Exposure} && (+) \\
&+ B3 \cdot Z(SIZE)[it] \ (-) && \text{Firm Size} && (-) \\
&\quad B4 \ \ Z(LEV)[it] \ (+) && \text{Leverage} && (+) \\
&+ B5 \cdot Z(PROF)[it] (-) && \text{Profitability} && (-) \\
&\quad B6 \cdot Z(BM)[it] \ \ (+) && \text{Market Beta} && (+) \\
&+ a(i) && \text{Firm Fixed Effects} \\
&+ y(t) && \text{Year Fixed Effects} \\
&+ e(it) && \text{Error Term}
\end{aligned}
$$

Where i = individual firm, t = year, and (+) / (–) show whether that variable pushes the cost of debt up or down.

Symbol	Variable / Term	Expected Effect on Cost of Debt
$Y(CoD)_{[it]}$	Cost of Debt	Dependent Variable
$X(CDS)_{[it}$	Climate Disclosure Score	(–) Decreases
$X(CRE)_{[it}$	Carbon Risk Exposure	(+) Increases
$Z(SIZE)_{it}$	Firm Size	(–) Decreases
$Z(LEV)_{[it}$	Leverage	(+) Increases
$Z(PROF]_{[it]}$	Profitability	(–) Decreases
$Z(BM)_{[it}$	Market Beta	(+) Increases
$a(i)$	Firm Fixed Effects	Control for time-invariant firm characteristics
$y(t)$	Year Fixed Effects	Control for common shocks across years
$e(it)$	Error Term	Idiosyncratic error

Where i = individual firm, t = year, and (+) / (–) show whether that variable pushes the cost of debt up or down.

Why Use This Method?

The biggest challenge in disclosure research is a problem called endogeneity. This is the risk that financially stronger companies tend to both disclose more and have lower costs of capital - not because disclosure causes lower costs, but simply because they are better-run companies to begin with.
If we don't account for this, we might wrongly conclude that improving disclosure reduces costs of capital, when in reality it's just that better-run firms happen to do both things at once.

The fixed effects model solves this by holding each company's stable background characteristics constant. This means we only look at whether a company's costs of capital changed in the same years that its disclosure quality changed - giving a much cleaner and more reliable result.

Event Study Methodology for Market Reactions

This section uses the event study methodology to measure how the stock market reacts in the short term to specific, datable events - such as when a company or regulator publishes a new climate disclosure.
This method is based on the semi-strong form of the **Efficient Market Hypothesis (EMH)**, which says that stock prices should react immediately and fully to any new public information. By studying what happens to share prices around a disclosure announcement, we can measure how much the market values that information.

How the Event Study Works
While the concept is straightforward, the method involves several steps:
1. **Identify the event** - pinpoint the exact date that new climate-related information was made public.
2. **Set the event window** - the period studied around the event. This is typically one day before and one day after the announcement, but can be wider if the market takes longer to react.
3. **Measure the stock price reaction** - compare what the stock actually did during the event window with what it would normally have been expected to do.

For example, when the Reserve Bank of India published its Draft Climate-related Financial Risks Disclosure Framework in February 2024, that is one datable event. The event window would cover the day of the announcement plus one day before it.

Abnormal Returns and Cumulative Abnormal Returns

To estimate what a stock would normally have returned without the event, we use historical return data - typically from 120 to 250 trading days before the event. This gives us an expected or 'normal' return.

- **Abnormal Return (AR) = Actual return minus the expected normal return**. This shows how much the stock moved specifically because of the event.
- **Cumulative Abnormal Return (CAR) = The sum of all daily abnormal returns across the event window**. This is the key measure of the overall market reaction to the disclosure event.

Statistical tests - including t-tests for normal distributions and Wilcoxon sign-rank tests for non-normal distributions - are used to confirm whether the observed reactions are statistically significant and not just random noise.

Financial Indicators and Variables

The financial variables chosen for this study determine how much useful information can be extracted from the analysis. Each variable captures a different way in which markets respond to climate-related information. The four main financial variables used in this research are: cost of equity, bond spreads, stock returns, and sectoral investment flows.

Cost of Equity and Investor Risk Perception

The cost of equity is the return that an investor expects to earn in exchange for investing money into a company. The riskier the company appears, the higher the return investors will demand before they are willing to invest.
When a company discloses its climate-related risks clearly and transparently, it reduces what is called information asymmetry - meaning investors have less uncertainty about the company's future. With less uncertainty, investors are more comfortable accepting a lower return, which lowers the company's cost of equity.
In other words: **better climate disclosure - less investor uncertainty - lower cost of equity for the company.**

Bond Spreads and Credit Risk Pricing

When companies borrow money by issuing bonds, the interest rate they pay is usually higher than the rate on a 'risk-free' government bond. This extra amount - called the bond spread or yield spread - represents the premium investors demand for taking on the additional risk of lending to that company.
Bond spreads are a useful indicator of how credit markets are pricing a company's risk of defaulting on its debt. They are particularly sensitive to climate-related risks because bond investors are primarily focused on downside risk - they want to know if the company might suffer real financial losses from:
- **Physical climate risks** - such as damage from floods, droughts, or extreme weather events.
- **Transition risks** - such as stranded assets (e.g. oil reserves that can no longer be used) or new regulatory penalties as the economy moves away from carbon.

Stock Returns and Market Performance

Stock returns serve two roles in this study:

- In the event study (Section 7.1.2), daily stock returns are used to detect how quickly and how strongly the market reacted to a specific climate disclosure event.
- In the long-term portfolio analysis, stock returns allow us to compare the average performance of different groups of companies over time - particularly high-carbon versus low-carbon firms.

Event Study Application

In the event study, each firm's daily return is compared against a market benchmark to isolate the climate-specific price movement. The Abnormal Return shows how much a stock moved beyond what normal market conditions would have predicted on that day. Summing these across the event window gives the Cumulative Abnormal Return - the overall market reaction.

Research using this method consistently finds that announcements of mandatory climate disclosures produce a negative market reaction, and that carbon-intensive firms see larger stock price declines than low-carbon firms.

Long-Run Portfolio Analysis

Over the longer term, this study compares portfolios grouped by climate-related factors such as carbon emissions, transition risk scores, and green patents.

- **High-carbon firms tend to generate higher average returns over time** - because investors demand a risk premium as compensation for the added carbon-related uncertainty they are taking on.
- **Low-carbon and climate-solution companies have often produced lower returns than their potential would** suggest - indicating that markets are still undervaluing the future cash flows of businesses that stand to benefit from a shift to a low-carbon economy.

Sectoral Investment Flows

Beyond tracking individual companies, this study also looks at how capital is shifting between entire sectors of the economy. This macro-level analysis shows how climate-related concerns are changing where money flows at an economy-wide scale.

Sectoral Trends

Carbon-intensive sectors - including fossil fuel energy, utilities, heavy materials, and transportation - are facing growing pressure to give up capital. Divestment campaigns have expanded significantly: an estimated **1,485 institutional investors**, representing approximately **US$39.2 trillion** in assets, have made commitments to divest from fossil fuels globally.

At the same time, large amounts of capital are flowing into:

- Renewable energy
- Clean technology
- Green real estate
- Climate finance products

This capital transition is not speculative. Evidence from the corporate bond market, equity fund flows, and corporate finance decisions shows that this shift is already underway and measurable.

Why Sectoral Flows Matter

Tracking where capital moves between sectors is critical for understanding how the future cost of financing will develop across industries. As more capital flows toward low-carbon sectors, the cost of financing for carbon-intensive companies rises - which in turn increases the pressure on those companies to transition their business models.

The connection between climate disclosure, the cost of capital, and sectoral capital flows is the core mechanism through which climate finance markets create real-world economic change.

What Does Each Variable Mean?

Symbol	Variable	Direction	In Simple Terms
Y(CoE)	**Cost of Equity (Dependent)**	-	The outcome in Equation 1. The return equity investors expect from the company.
Y(CoD)	**Cost of Debt (Dependent)**	-	The outcome in Equation 2. The extra interest a company pays on bonds above the risk-free rate.
X(CDS)	Climate Disclosure Score	**Inverse (–)**	Better disclosure → less investor uncertainty → they accept a lower return. Higher score = lower cost of capital.
X(CRE)	Carbon Risk Exposure	**Direct (+)**	More carbon risk → higher chance of future losses → investors demand more return as compensation.
Z(SIZE)	Firm Size	**Inverse (–)**	Bigger companies are seen as more stable → lower risk → investors accept a lower return.
Z(LEV)	Leverage (Debt Level)	**Direct (+)**	More debt → more financial pressure on the company → investors want higher compensation.
Z(PROF)	Profitability	**Inverse (–)**	More profitable companies are less likely to default - investors accept a lower return.
Z(BM)	Market Beta	**Direct (+)**	Higher sensitivity to market swings - more risk - investors demand a higher return.
a(i)	Firm Fixed Effects	-	Captures hidden, stable differences between companies (e.g. management quality) that don't change over time.
y(t)	Year Fixed Effects	-	Captures economy-wide changes in a given year that affect all companies equally.
e(it)	Error Term	-	The part of the result the model cannot explain - random variation left over after all variables are accounted for.

CASE STUDIES

Section 8

CASE STUDIES

Climate Disclosure and US Equity Markets

The United States capital market offers one of the most closely studied environments for assessing whether climate disclosure moves asset prices. This is partly because of market size, partly because of the contested nature of the regulatory process, and partly because the combination of voluntary disclosure and delayed mandatory requirements created a natural experiment: if disclosure matters to investors, evidence of it should show up even before rules require it.

Research published in the Journal of Financial Economics found that firms with stronger carbon disclosure scores commanded lower costs of equity capital, as institutional investors interpreted disclosure quality as a proxy for risk management maturity. The implication is that markets had already begun pricing climate governance well before any regulator mandated it.

The SEC's proposed climate disclosure rules in March 2022 sharpened this further. Their announcement produced negative abnormal returns for carbon-intensive sectors while firms with existing robust ESG disclosure frameworks saw minimal price movement, consistent with the view that better-prepared firms had already absorbed the compliance cost signal into their valuations.

When the SEC finalised a narrower version of its rules in March 2024, with Scope 3 reporting dropped after sustained industry opposition, the market reaction was muted, suggesting that the Scope 3 retreat had been widely anticipated.

The table below summarises the principal transmission channels through which climate risk enters equity valuations by sector:

Sector-wise Disclosure Requirements

Sector	Dominant Risk	Financial Channel	Disclosure Quality	Disclosure Notes
Energy (Oil & Gas)	Transition	Stranded assets; capex write-downs	Low – Moderate	Scope 1 & 2 reported; Scope 3 absent. No scenario analysis.
Utilities	Physical & Transition	Compliance costs; infra capex	Moderate	TCFD physical mapping improving; target-setting inconsistent.
Financial Services	Portfolio / Counterparty	Credit exposure to carbon-intensive borrowers	Improving	Financed emissions increasingly reported; PCAF coverage patchy.
Technology	Reputational & Scope 3	Data centre energy; supply chain emissions	High	Scope 1 & 2 third-party assured; Scope 3 supply chain gaps remain.
Real Estate	Physical	Asset devaluation in exposed zones	Low	Asset-level risk rarely quantified; EPCs used as proxy.

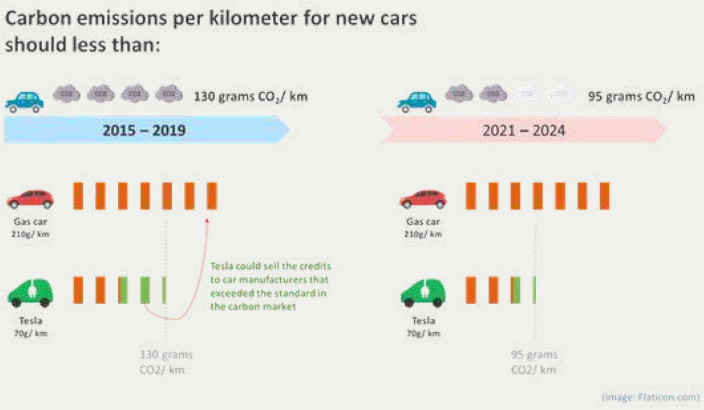
Tesla: Carbon Credit Revenues and the Economics of Regulatory Arbitrage

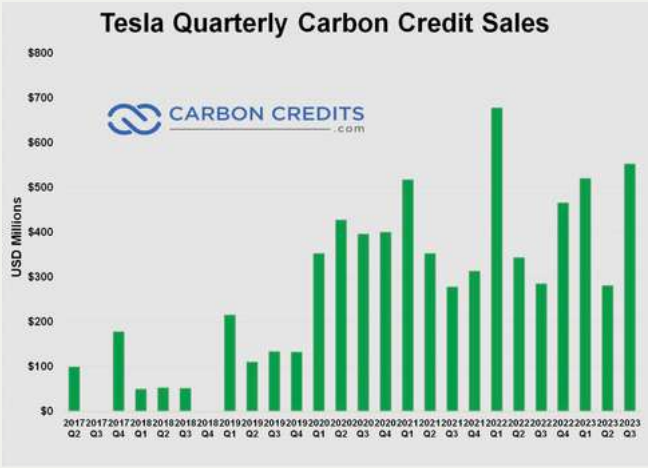
Tesla's carbon credit business is one of the more underappreciated stories in recent corporate finance, and one of the clearest available illustrations of how regulatory design creates asymmetric value across competitors within the same industry.

Tesla generates regulatory credits by exceeding zero-emission vehicle mandates in California and other US states. It then sells those credits to legacy automakers who cannot meet the mandates through their own fleets. As CarbonCredits.com reported citing Tesla's SEC filings, Tesla's total carbon credit revenue for 2024 surged to $2.76 billion, marking a 54% year-over-year increase from $1.79 billion in 2023, and since 2017, Tesla's total earnings from these transactions have exceeded $10.4 billion, making it one of the most lucrative aspects of the business.
The financial trajectory of this revenue stream is worth examining in detail:

Two observations warrant particular attention. In fiscal 2020, Tesla's first profitable year as a public company, carbon credit revenues actually exceeded net income, meaning the core vehicle business was still loss-making. Carbon market revenue was what made the difference. In 2024, as core vehicle margins came under pressure from price cuts and intensifying competition, the credits again became a material profitability buffer, accounting for approximately a third of net income.

The strategic implication for the broader EV industry is significant. First-mover advantage in electrification generates regulatory rents that late movers cannot easily replicate. By the time traditional automakers produce enough zero-emission vehicles to generate surplus credits, the market for those credits will have thinned as fleet-wide compliance improves across the industry. This dynamic is material for analysts valuing first-mover EV companies relative to incumbents undergoing delayed transitions.





Fiscal Year	Carbon Credit Revenue	Net Income	Credits as % of Net Income
2019	$594M	($862M)	N/A (net loss)
2020	$1,580M	$721M	~219%
2021	$1,465M	$5,519M	~27%
2022	$1,776M	$12,556M	~14%
2023	$1,790M	$14,974M	~12%
2024	$2,760M	$8,400M	~33%

Whether this revenue stream is durable is an open question. Despite predictions that demand for these credits would decline as more automakers ramp up electric vehicle production, Tesla's earnings from this segment have remained strong, driven by the slow pace of EV adoption among traditional car manufacturers and increasingly strict emissions regulations.

What this illustrates for the broader research is that carbon market design produces direct, measurable financial outcomes at the firm level. Tesla's credit revenues are a transfer payment from firms behind on the transition to the one furthest ahead, and the mechanism driving that transfer is precisely the regulatory compliance structure this paper examines. The credit stream may narrow as competitors catch up, but the underlying point holds: transition positioning carries quantifiable financial value, and firms that have embedded climate strategy into core operations carry advantages that conventional financial analysis does not yet fully capture.

British Petroleum (BP): When Transition Strategy Meets Investor Pressure

BP's trajectory between 2020 and 2025 is worth examining in detail because it compressed into five years a cycle most analysts expected to unfold over a decade. It is also the most visible available case study of what happens when a fossil fuel major makes ambitious climate commitments, fails to operationalise them with matching capital allocation, and then faces a shareholder revolt demanding reversal.

In February 2020, then-CEO Bernard Looney announced that BP would reduce oil and gas production by 40% by 2030 while rapidly scaling renewable investment. Al Jazeera reported that BP's carbon-cutting target, announced in 2020, stood out at the time as one of the most ambitious in the industry. What followed was a case study in the gap between strategic narrative and capital allocation. Oxford Executive Institute's analysis noted that activist investors, particularly Elliott Management, argued that BP's aggressive pivot to renewables was jeopardising short-term financial performance and reducing shareholder value, and lobbied for a renewed focus on fossil fuels.

By February 2025, the reversal was complete. BP's Capital Markets Day filing with the SEC confirmed that BP had fundamentally reset its strategy, increasing oil and gas investment to approximately $10 billion per year, growing production targets to 2.3 to 2.5 million barrels of oil equivalent per day by 2030. Simultaneously, Offshore Magazine reported that BP cut renewable energy spending by more than $5 billion per year as part of the reset. The investor response to this reversal is instructive and, from a climate policy standpoint, uncomfortable. BP's share price fell only 1.8% on the announcement, which CarbonCredits.com noted reflected mixed market sentiment, with some investors welcoming the renewed focus on profits while others expressed concern that BP was abandoning long-term sustainability positioning.

Microsoft: Internal Carbon Pricing as a Governance Tool

Microsoft's approach to climate governance is worth examining not because it is free of contradictions, but because it represents the most developed and most transparently documented corporate experiment in using internal carbon pricing as a behaviour-change mechanism rather than an accounting convention.

Microsoft's official blog confirmed the company's commitment in January 2020: by 2030, **Microsoft will be carbon negative, and by 2050**, it will remove from the environment all the carbon it has emitted, directly or through electricity consumption, since the company was founded in 1975. This went significantly further than carbon neutrality, which involves offsetting current emissions, and committed the company to erasing its entire historical footprint.

The mechanism driving this is an internal carbon fee applied to all business divisions. **Microsoft's industry blogexplains that starting in 2012, Microsoft's initial carbon fee focused on Scope 1, Scope 2, and business air travel, with the proceeds funding its carbon-neutral commitments; in 2020, the company began charging business groups for all Scope 3 emissions and simultaneously worked with suppliers to understand and reduce their carbon contributions.**

The fee escalation is significant. **As reported by Trellis, Microsoft charges a carbon fee of $15 per tonne across all three scopes, but raised the Scope 3 business travel fee to $100 per metric tonne of CO2 equivalent to better support the purchase of sustainable aviation fuel.** At $100 per tonne, business travel becomes a material cost item for any division generating substantial air miles, creating a genuine financial incentive to substitute remote engagement.

There is, however, a significant complication that the company has been transparent about. Microsoft's March 2022 sustainability update acknowledged that while the company achieved a 17% reduction in Scope 1 and 2 emissions year over year, Scope 3 emissions increased by 23%, driven by capital equipment expenditures, new

datacenter construction, and higher product usage. This is the tension that haunts every technology company with an absolute emissions commitment: cloud computing and AI infrastructure growth creates a Scope 3 problem that is structurally difficult to decouple from revenue growth.

In February 2025, Trellis reported that Microsoft announced it would stop purchasing non-additive, unbundled renewable energy certificates, which many corporations buy from brokers to offset emissions and claim carbon neutrality, redirecting those funds toward long-term, higher-impact carbon removal projects and clean electricity procurement. This pivot signals a meaningful shift in what credible corporate climate accounting looks like, moving away from paper offsetting toward genuine emissions reduction infrastructure. Whether it reflects growing integrity in climate governance or a belated acknowledgement that earlier approaches were not working is a matter of interpretation, but the directional shift is significant.

Adani Green Energy: Scale, Capital Markets, and the Complexity of India's Transition

Adani Green Energy Limited presents a qualitatively different kind of case study from the preceding four. It is not primarily about disclosure quality or internal governance mechanisms. It is about what large-scale renewable energy deployment looks like when it is financed through global capital markets in an emerging economy context, with all the geopolitical and conglomerate-level governance complexity that entails.

AGEL is, by installed capacity, the largest renewable energy company in India. Its FY 2023-24 Annual Reportconfirmed the company had achieved 10.9 GW of renewable capacity against a stated 2030 target of 50 GW.

Its flagship project at Khavda, Gujarat, is planned to be the world's largest single renewable energy installation at 30 GW. The scale of AGEL's ambition in this regard is a legitimate and material part of India's energy transition story.

The company has accessed international green capital through multiple channels: Long-term power purchase agreements with SECI (Solar Energy Corporation of India) and NTPC USD-denominated green bond issuances targeted at ESG-oriented international investors.

Equity capital from sovereign wealth funds and global institutional investors. A recently announced partnership with TotalEnergies as a strategic shareholder. On ESG ratings, AGEL has performed strongly by international benchmarks, receiving top-tier ratings from ISS ESG, Sustainalytics, and CRISIL. These ratings reflect genuine operational performance: the company's capacity utilisation, clean energy generation data, and emissions avoided are verifiable and substantial.

However, AGEL cannot be analysed in isolation from the broader Adani Group's governance controversies. The Hindenburg Research report of January 2023 made allegations about stock manipulation and accounting irregularities across the Adani conglomerate. While the allegations did not specifically target AGEL's renewable operations, the market reaction was immediate and severe: Adani Group companies lost over $100 billion in combined market capitalisation within days of the report's publication.

Infosys: Carbon Neutrality Strategy and the Limits of Offsets

Infosys occupies an unusual position in India's ESG landscape. It is the most cited domestic case of a large listed company that achieved a substantive climate target ahead of schedule, and it has done so with a degree of methodological transparency that is uncommon among Indian corporates. It is also, on closer inspection, a case study in why carbon neutrality claims require careful reading. Infosys's official climate disclosures confirm that the company achieved carbon neutrality in fiscal 2020 across all three emission scopes, 30 years ahead of the timeline set by the Paris Agreement, building its carbon neutral programme on three pillars: energy efficiency to reduce emissions, renewable energy to avoid emissions, and carbon offsets to mitigate remaining emissions.

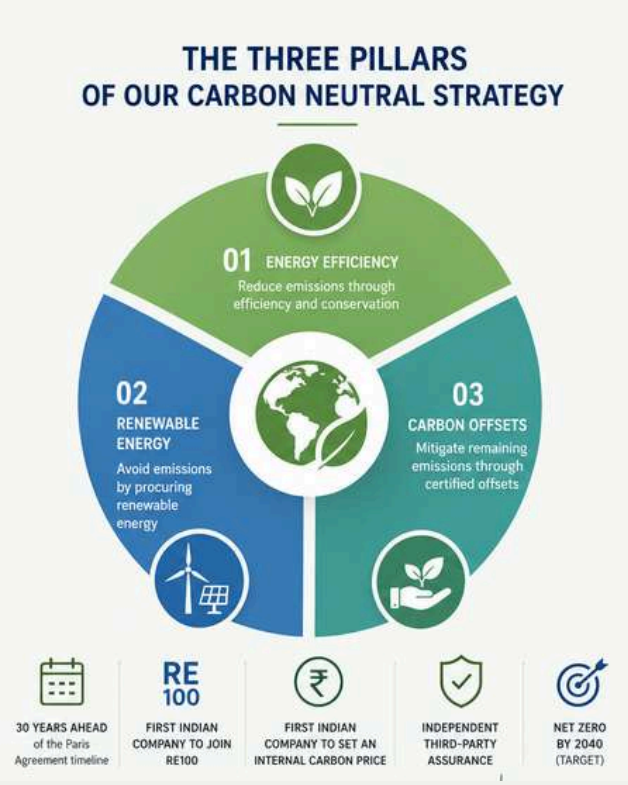
The scope of this achievement matters. **Infosys's BRSR disclosure for FY 2023-24 confirmed that the company has been carbon neutral since fiscal 2020 across all emissions (Scope 1, 2 and 3) and has continued to maintain that status annually, with its approach validated through independent third-part assurance, It is also the first Indian company to join RE100, the global corporate renewable energy initiative, and the first Indian corporate to have set an internal carbon price, as confirmed in its ESG Report 2022-23.** A FICCI ESG Summit compendium noted that among the NIFTY50 companies, all six IT services firms had disclosed a net zero target, with Infosys leading the cohort as it has been carbon neutral since 2020 and plans to achieve net zero by 2040.

There are, however, questions worth raising about the methodology underpinning these claims. Infosys's carbon neutrality relies partly on carbon offset purchases from projects it operates directly and through third-party Gold Standard-certified registries. As ResearchGate's analysis of Infosys sustainability reporting notes, sustainability reporting in the Indian IT sector faces scrutiny due to lack of transparency and the potential for manipulation, given the absence of standardised reporting protocols, and despite companies' claims of commitment to carbon neutrality, climate pledges are rarely independently stress-tested for rigour.

The broader insights this case generates for the research are the following:
Carbon neutrality achieved through operational efficiency improvements and renewable energy procurement is qualitatively more credible than neutrality achieved primarily through offset purchases. Infosys's early adoption of internal carbon pricing, TCFD-aligned reporting, and third-party assurance under BRSR Core sets a benchmark that SEBI's framework is now seeking to extend to the broader listed market.

The 30-year claim (ahead of the Paris timeline) is accurate in narrow accounting terms, but should be assessed against the company's actual Scope 3 footprint, particularly in supply chain and capital goods, which are acknowledged to be excluded from neutrality calculations. As a service sector company with relatively low physical-asset intensity, Infosys's path to carbon neutrality is structurally easier than that of manufacturing-heavy listed companies; drawing direct policy lessons requires acknowledging this differencehe company's disclosure practices nonetheless represent the most developed example currently available within Indian listed markets of what SEBI's BRSR Core framework is trying to institutionalise at scale.

What makes the Infosys case relevant to the disclosure credibility question is not the carbon neutrality claim itself but the architecture behind it: documented methodology, external assurance, and an internal carbon price that connects the commitment to actual spending decisions. That combination is what separates credible climate accounting from a reporting exercise, and it is the standard that SEBI's BRSR Core framework is now attempting to extend to Indian listed markets at scale.



POLICY IMPLICATIONS

Section 9

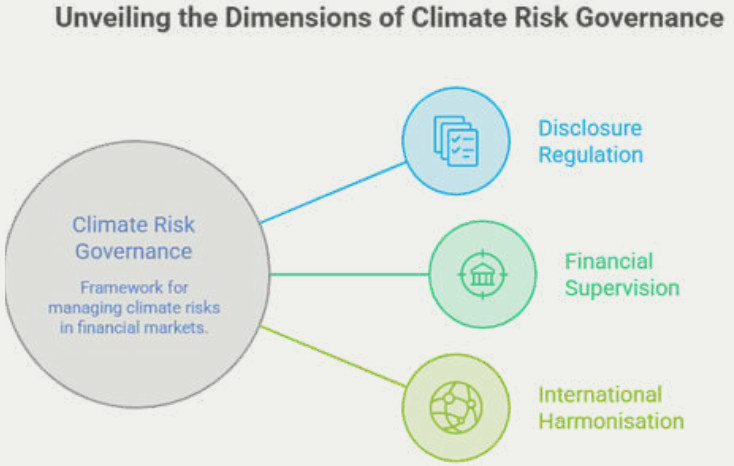
POLICY IMPLICATIONS

Implications for Financial Regulators

TThe findings of this report suggest that the experiment with voluntary climate disclosure has largely reached its limits. Frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD) played a crucial role in creating a common language for reporting climate-related risks and opportunities. However, evidence from the 2018-2022 period shows that the quality of disclosures varied significantly across firms. While some companies provided detailed scenario analyses and measurable climate-related information, many disclosures remained largely qualitative, making meaningful comparisons across firms difficult.

This creates an important challenge for investors and regulators. When firms use different assumptions, methodologies, and reporting standards, disclosures become difficult to compare and less useful for assessing risk. As a result, there is a growing need for mandatory and standardised reporting frameworks. The publication of IFRS S1 and IFRS S2 by the International Sustainability Standards Board (ISSB) in 2023 marked a significant step in this direction. These standards were specifically designed to address the inconsistencies observed under voluntary disclosure regimes and provide a credible global baseline for sustainability and climate-related reporting. Jurisdictions that have not yet adopted or endorsed ISSB standards should actively consider doing so, as fragmented reporting systems reduce transparency and create opportunities for regulatory arbitrage.

The Corporate Sustainability Reporting Directive (CSRD) adopted by the European Union goes beyond the ISSB framework through its emphasis on double materiality. Under this approach, firms must disclose not only how climate-related issues affect their financial performance, but also how their own operations and value chains impact society and the environment. While this significantly enhances transparency and accountability, it also creates substantial compliance challenges, particularly for smaller listed firms and auditors. Regulators must therefore consider phased implementation, sector-specific guidance, and practical support mechanisms to ensure that reporting requirements improve decision-making rather than becoming a purely compliance-driven exercise.



Climate risk should also become a more integral component of financial supervision. The work of the Network for Greening the Financial System (NGFS) has provided regulators with valuable climate scenarios that can be used in stress testing exercises. Similarly, the Bank of England's Climate Biennial Exploratory Scenario (2021) demonstrated how different climate pathways can affect banks' balance sheets and insurers' liabilities through both physical risks and transition risks. Such exercises should become more widespread, and their findings should increasingly inform supervisory practices, capital planning, and risk management frameworks. Over time, climate-related risks should be formally incorporated into Pillar 2 supervisory assessments, particularly for institutions with significant exposure to carbon-intensive sectors and long-duration assets.

Finally, greater international coordination and harmonisation remain essential. Despite recent progress, firms operating across jurisdictions continue to face multiple reporting frameworks, including ISSB standards, the CSRD, SEC disclosure requirements, and India's BRSR framework. These differing standards often use different definitions, materiality thresholds, and assurance requirements, making cross-border comparisons difficult for investors. Addressing this challenge will require stronger cooperation among regulators and standard-setting bodies to ensure that climate disclosures become more consistent, comparable, and decision-useful across global financial markets.

Implications for Corporations

The corporate implications of this research period come down to a fairly blunt observation: **climate risk management as typically practised at most companies is not yet fit for purpose**. In many organisations, climate strategy still lives in the sustainability or ESG team, produces a report once a year, and has limited influence on core business decisions, such as capital allocation, pricing, procurement, and product development. The firms that are genuinely ahead of this are the ones that have moved climate considerations into the CFO's office and the board risk committee, where they actually affect how money gets spent.

Internal carbon pricing is probably the most underutilised practical tool available to firms today. The idea is straightforward: attach a shadow price to tonnes of CO_2 emitted, and require business units to factor that cost into investment appraisals, procurement decisions, and R&D allocation. Microsoft has used this mechanism to fund its internal sustainability initiatives. Business units that exceed their carbon budget effectively pay into a central fund that supports renewable energy procurement and other decarbonisation programmes.

nfosys took a similar route and managed to achieve carbon neutrality years ahead of many peers by embedding these incentives into how business decisions were evaluated day-to-day. The World Bank's Carbon Pricing Leadership Coalition found that over 2,000 companies had adopted or were planning to adopt internal carbon pricing by 2022, though the range of prices used, from a derisory USD 5 per tonne to over USD 150, shows how inconsistently the tool is being applied.

The range of prices being applied from USD 5 to over USD 150 per tonne reflects significant variation in how the tool is being used. The science-based targets literature indicates that prices in the lower end of this range are unlikely to influence capital allocation decisions in any material way. The CPLC's own analysis and practitioner-facing guidance consistently reference a range of USD 50 to 150 and above as the threshold at which internal carbon pricing begins to have meaningful behavioural effects on investment and procurement decisions.

On disclosure, **investor expectations have shifted considerably since 2018**, and companies that have not kept pace are starting to feel consequences. Activist shareholders have pushed climate resolutions at major energy and banking companies with increasing success rates. ESG-focused lenders have started adding climate-linked covenants to loan agreements. Rating agencies are beginning to incorporate transition risk assessments into their credit methodology.

Against this backdrop, a boilerplate sustainability report with cherry-picked metrics is not just insufficient. It actively signals to sophisticated investors that management does not fully understand its own climate exposure. The BP case study in this research illustrated this clearly: when BP disclosed its transition risk analysis and announced its renewable energy pivot, the market reaction was closely watched and had visible effects on both its valuation and bond spreads. The lesson is not necessarily to copy BP's specific strategy, but to take seriously the market's increasing interest in **credible, quantitative climate disclosure**.

One thing that consistently gets underweighted in the corporate climate conversation, and deserves more attention here, is **adaptation**. Almost all corporate climate strategy is about mitigation, covering things like reducing emissions, buying renewable energy, and setting net-zero targets. That matters, obviously. But for a growing number of companies, **physical climate risks are already affecting operations** in ways that require strategic responses independent of what happens on the emissions side.

Supply chains running through climate-vulnerable geographies, manufacturing facilities in flood-prone areas, and agricultural inputs exposed to water stress are all active financial risks that require adaptation investment regardless of what any company does to its own carbon footprint. The IPCC's **Sixth Assessment Report** is quite explicit that even under optimistic emissions scenarios, significant physical climate impacts are now locked in for the coming decades.

Implications for Capital Markets

There is a common saying in climate finance that **"climate risk is financial risk."** While the phrase is now widely used by regulators and central banks, evidence from the 2018-2025 period suggests that financial markets have been relatively slow to fully reflect this reality.

The evidence is increasingly visible. **Carbon-intensive sectors**, including energy, heavy industry, and high-emissions transport, underperformed during several periods following major climate policy announcements such as the EU Green Deal and the **US Inflation Reduction Act.** ESG-screened indices also outperformed conventional benchmarks in a number of years, although this was partly influenced by sector composition rather than pure climate risk repricing. At the company level, the BP case study provides a clear example. Following the disclosure of its transition risk analysis and its strategic shift towards renewable energy, the market responded quickly, with measurable effects on both **equity valuation and bond spreads.**

This highlights a broader trend. Investors are no longer treating climate disclosures as a compliance exercise. They are increasingly comparing disclosures across firms and assessing whether corporate actions match stated climate commitments. Although the repricing process remains uneven and incomplete, it is clearly underway. The growth of **global sustainable investment assets to over USD 30 trillion by 2022** further reflects the growing importance of climate considerations in investment decisions.

At the same time, there are important limitations within the **ESG investment** landscape. Many strategies labelled as ESG investments rely primarily on exclusion screens, such as avoiding tobacco, weapons, or fossil fuels, without fully analysing how climate risks differ across sectors and geographies. More advanced approaches, including **transition risk modelling, physical risk mapping, and climate value-at-risk frameworks,** provide deeper insights but remain technically demanding and are still developing.

A similar challenge exists in climate stress testing. Frameworks such as the **NGFS** scenarios extend several decades into the future, making them difficult to translate into present-day credit and risk management decisions. Financial institutions have begun supplementing these scenarios with borrower-level analysis, but this requires reliable Scope 1, Scope 2, and Scope 3 emissions data, which many firms still do not disclose consistently. As a result, a cycle emerges where banks need better emissions data to conduct meaningful stress tests, while firms face limited pressure to provide such data until stress testing carries stronger supervisory consequences. Addressing this issue will require regulatory action on both sides.

The challenge of **capital allocation** remains equally significant. According to the **International Energy Agency (IEA),** clean energy investment must roughly triple by 2030 compared to 2022 levels if the goal of limiting warming to **1.5°C** is to remain achievable. Meeting this gap will require more than green bonds and blended finance instruments. It will depend on a broader shift in how financial markets price climate-related risks and opportunities.

In this context, **transition finance** is likely to play a critical role. Financing high-emitting companies that are genuinely pursuing decarbonisation may ultimately have a greater climate impact than focusing solely on firms that already have low-carbon business models. Consequently, banks and asset managers that develop expertise in evaluating and structuring transition finance opportunities are likely to be better positioned than those that simply exclude carbon-intensive assets from their portfolios.

Key Regulatory Frameworks: Coverage, Gaps, and How They Complement Each Other

Framework	Primary Focus	What It Does Well	Key Gap	Which Framework Addresses the Gap
TCFD (2015)	Voluntary disclosure: governance, strategy, risk, metrics	Established a shared vocabulary; drove early adoption globally	No enforcement mechanism; inconsistent implementation quality	ISSB mandates the TCFD structure within binding financial reporting
ISSB / IFRS S1 & S2 (2023)	Global baseline for sustainability + climate disclosure in financial filings	Standardises reporting across jurisdictions; integrates with existing financial infrastructure	Single materiality only - does not require companies to report societal/environmental impact	CSRD fills this gap through double materiality
CSRD / ESRS (EU)	Double materiality - financial impact on company AND company's impact on environment/society	Most comprehensive scope; forces companies to look outward, not just inward	Significant compliance burden, especially for smaller firms; risk of box-ticking	ISSB's lighter baseline can serve as an entry point for markets not yet ready for full CSRD-level requirements
NGFS Scenarios	Climate scenario framework for central banks and supervisors	Long-horizon stress testing (to 2050+); covers physical and transition risks	Multi-decade timeframes are hard to translate into near-term credit decisions	Bottom-up counterparty analysis by banks complements macro NGFS scenarios at the firm level
FSB Harmonisation Efforts	Cross-jurisdictional coordination on disclosure + supervision	Provides a forum for regulatory convergence	Progress has been slow; lacks enforcement capacity	Political commitment from individual jurisdictions required to move coordination from talk to action

Connecting the Three Policy Areas: Where One Falls Short, Another Steps In

Policy Challenge	Financial Regulators	Capital Markets	Corporations	How the Gap Gets Filled
Data quality and comparability	ISSB and CSRD mandate standardised disclosures, but adoption is uneven across jurisdictions	Investors cannot price climate risk properly without comparable data across firms	Many companies still do not disclose Scope 1, 2, and 3 consistently	Regulatory mandates (9.1) create the data that capital markets (9.2) need; corporate reporting pressure (9.3) follows when investors and lenders start demanding it
Pricing of climate risk	Supervisors are beginning to require climate stress tests, but capital requirements have not formally changed	Carbon-intensive sectors are starting to reprice, but the process is uneven and incomplete	Internal carbon pricing remains inconsistently applied (USD 5 to USD 150 range)	Supervisory capital requirements (9.1) should eventually force banks to price transition risk into lending; that feeds back into corporate financing costs (9.3)
Short-termism in decision-making	NGFS scenarios run to 2050+, which is hard for supervisors to translate into near-term policy levers	Quarterly reporting cycles and fund benchmarks create structural pressure to ignore long-horizon risks	Climate strategy often sits outside the CFO's office, disconnected from capital allocation	Capital markets create shorter-term incentives through ESG covenants, activist lenders, and rating agency methodology changes-filling the gap where regulatory timelines are too long
Transition finance gap	Regulation does not yet systematically incentivise lending to high-emitting firms that are genuinely decarbonising	Most ESG strategies exclude brown assets rather than engaging with companies in transition	Companies in transition face higher financing costs and less investor engagement	Banks and asset managers with genuine transition finance expertise (9.2) can fill the gap; regulatory guidance on what qualifies as credible transition (9.1) reduces greenwashing risk
Physical climate risk and adaptation	Stress testing frameworks are skewed toward transition risk; physical risk modelling is less developed	Physical risk is harder to price in equity markets-geographically specific and long-dated	Adaptation is almost entirely absent from corporate climate strategy despite IPCC warnings	All three areas reinforce the same blind spot-and all three need to move simultaneously to close it

RISKS, LIMITATIONS & CHALLENGES

Section 10

RISKS, LIMITATIONS & CHALLENGES

Measurement Challenges

The **most fundamental problem** in quantitative climate finance research is the **state of the underlying data**. This goes well beyond the usual concerns about data quality. It reflects a deeper, structural problem with how ESG and climate metrics are constructed and measured. Take the **simplest case**: a company's carbon footprint. Depending on whether you are looking at Scope 1 emissions only (direct emissions from operations), Scope 1 and 2 (including purchased energy), or Scope 1, 2, and 3 (including the full value chain: suppliers, products in use, end-of-life), you can get numbers that differ by an order of magnitude. Scope 3 in particular, which typically accounts for **70 to 90 percent** of total lifecycle emissions for consumer-facing companies, is notoriously difficult to measure, relies heavily on estimates and industry averages, and is currently disclosed voluntarily by only a fraction of firms.

But even setting aside the scope question, different ESG data providers arrive at systematically different conclusions about the same company using the same or similar data. A foundational **study by Berg, Koelbel, and Rigobon at MIT Sloan** estimated the average correlation between ESG ratings from major providers at only 0.54, far lower than the near-perfect agreement that characterises credit ratings from Moody's, S&P, and Fitch. They identified **three main sources of this divergence**: differences in what attributes are measured, differences in how those attributes are weighed, and what they call rater effect, a kind of halo bias where a positive rating on one dimension inflates scores on others. For researchers, this means that any finding about the relationship between ESG performance and financial outcomes is **sensitive to the choice of data provider** in ways that are very hard to fully account for in robustness checks.

Data availability is another issue that does not get enough attention in developed-market-focused research. The firms that typically appear in ESG datasets are large, publicly listed companies, predominantly from North America, Europe, and parts of East Asia, that have the resources and incentive to produce detailed sustainability disclosures. Smaller firms, private companies, and companies headquartered in emerging markets are systematically under-represented, often not because they are performing poorly on climate metrics but simply because they are not disclosing at all. This weakens comparability, introduces structural bias, and limits the reliability of empirical conclusions in climate finance. Given that global emissions growth is heavily concentrated in developing economies, and that supply chain emissions connect developed-market companies to these geographies in complex ways, this data gap is not just a statistical inconvenience. It creates a **materially incomplete picture** of where climate risk is concentrated in the global financial system.

Climate risk modelling involves layers of uncertainty that are worth being explicit about. The integrated assessment models used by the IPCC and the NGFS to construct climate scenarios are genuinely sophisticated, but they embed assumptions about technology cost curves, policy implementation rates, behavioural responses, and geopolitical trajectories that are inherently contested.

Tipping points, including the non-linear threshold effects like ice sheet destabilisation or permafrost methane release, are acknowledged in the scientific literature as significant potential amplifiers of physical climate risk, but they are extremely difficult to incorporate into financially tractable models. When financial risk assessments are built on top of IAM outputs, they inherit all of these uncertainties. **Presenting scenario analysis results as a range of plausible outcomes is much more intellectually honest than presenting them as point estimates**, and regulators and supervisors should probably push harder on this distinction when reviewing institutions' climate risk disclosures.

Carbon Market Limitations

The voluntary carbon market entered the most serious credibility crisis in its history during the 2022-2024 period, and an honest accounting of its limitations is essential to understanding both the reform agenda that followed and the long-term prospects for carbon finance as a tool of climate transition. The problems were not simply operational - they went to the foundational question of whether the instrument was doing what it claimed to do.

The most damaging blow came in January 2023, when a joint investigation by The Guardian, Die Zeit, and SourceMaterial assessed credits certified by Verra and concluded that **over 90 percent** of its rainforest offset credits were likely to be phantom credits representing no real emissions reductions. Several months later, a peer-reviewed study published in Science reached similar conclusions about the systematic overestimation of deforestation prevention across a range of forestry programmes. Major corporations including **Gucci, Disney, and Shell**, which had publicly claimed carbon neutrality on the basis of such credits, were found to have been relying on instruments that lacked the environmental integrity that had been represented to markets and investors. The overall

value of the voluntary carbon market fell from USD 1.9 billion in 2022 to USD 723 million in 2023, and credit volumes more than halved from 253.8 $MtCO_2e$. **REDD+ credits** - the single most popular project category - lost 62 percent of their value year-over-year in 2023. This was not a minor correction; it was a structural repricing of risk reflecting a fundamental loss of buyer confidence.

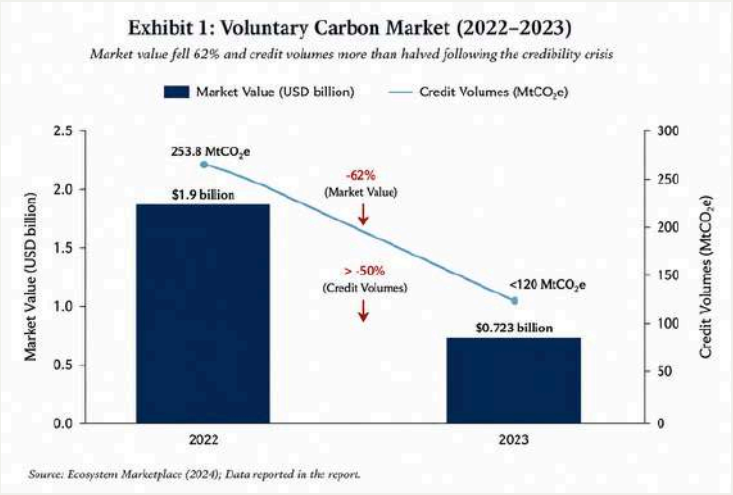
The **additionality problem** sits at the heart of this credibility failure and has proven the most technically intractable limitation of the voluntary market as it has operated to date. A carbon credit only carries environmental value if the emissions reductions it represents would not have occurred without the revenue generated by the credit itself - a counterfactual that is inherently difficult to prove.

The evidence accumulated over the 2018-2024 period suggests that a substantial proportion of issued credits relied on baselines that overstated deforestation risk, sequestration permanence, or renewable energy additionality. The **Core Carbon Principles** launched formally in 2023 by the **Integrity Council for the Voluntary Carbon Market** represent the most significant institutional response to this problem. By end of November 2025, the ICVCM had approved seven major carbon-crediting programmes and 36 methodologies against the CCP threshold. However, the implication for the legacy market was stark: all legacy renewable energy methodologies failed to meet the additionality standard, and approximately one-third of credits in circulation were found ineligible for the CCP label. Verra subsequently rejected 37 carbon credit projects and sanctioned four validation and verification bodies after satellite-based analysis revealed serious issues including the overstating of project areas - illustrating the extent to which the verification ecosystem had been structurally compromised by conflicts of interest, whereby registries earning fees per credit issued had inadequate incentives to police methodological rigour. While transaction volumes in the voluntary market fell 25 percent in 2024 compared to 2023, credit prices declined by only around 5.5 percent and retirement activity held fairly steady - pointing to a bifurcation between speculative and committed demand.

The market is visibly **repricing around quality**: removal credits traded at a 381 percent premium over reduction credits in 2024, up from 245 percent the previous year, and credits from recent project vintages commanded a 217 percent premium over older credits. This flight to quality is structurally healthy as it creates a genuine price signal for high-integrity supply, but it also weakens broader market price signals by leaving an overhang of older, lower-quality credits with weak demand.

The EU Emissions Trading System - the world's largest compliance carbon market by revenue throughout the research period - presents a distinct but related set of structural limitations. EUA prices, which had crossed €100 per tonne for the first time in February 2023, declined sharply through 2023 and into 2024, driven by a combination of weak industrial activity reducing demand, significant expansion of renewable energy production, falling natural gas prices, and increased auctioning volumes under REPowerEU. In 2024, 599 million allowances were auctioned, yielding EUR 39 billion in revenue - an 11 percent fall from 2023 despite a 15 percent volume increase, reflecting lower average prices. A structural concentration in market participation has persisted throughout the system's history: **approximately ten participants account for 90 percent of auctioned volumes**, with most EU ETS compliance entities sourcing allowances through financial intermediaries rather than engaging in primary markets directly.

The risk of **regulatory arbitrage** is perhaps the most structurally significant limitation of the voluntary carbon market for its long-term integration with the broader climate finance system. The absence of harmonised global standards across both **voluntary and compliance carbon markets** creates systematic incentives for participants to select the most permissive regime available, undermining environmental integrity. There are currently **78 direct carbon pricing instruments** operating globally, but the range of explicit carbon prices spans from near zero to over USD 160 per tonne of CO_2 equivalent - a spread that fundamentally distorts cross-border investment and production decisions. Only 20 percent of covered emissions are priced in line with the **Stern-Stiglitz Commission's recommendations.** This fragmentation also extends to the legal status of carbon credits, which varies from tradable commodity to regulatory compliance instrument to reputational signal depending on jurisdiction, creating acute uncertainty about ownership, enforceability, and the risk of double-counting. **China's ETS** currently operates without a total emissions cap, with allowances allocated in proportion to actual output rather than a fixed ceiling, meaning companies can expand production without tightening their absolute emissions position - a design feature that significantly limits the price signal's effectiveness in driving deep decarbonisation investment.



Regulatory Fragmentation

The single most consequential structural challenge for climate-related financial disclosure as a system is not any individual framework's design it is the proliferation of overlapping, non-identical regimes across jurisdictions, each with different conceptual foundations, materiality standards, assurance requirements, and reporting timelines. This fragmentation imposes direct compliance costs on multinationals, creates fundamental obstacles for the cross-jurisdictional comparability that investors require, and provides sophisticated actors with opportunities to engage in regulatory forum-shopping that erodes the quality and credibility of the overall disclosure ecosystem.

The current landscape is anchored by **two dominant frameworks** between which the world is dividing. A November 2024 publication from the **IFRS Foundation** reported that 30 jurisdictions representing more than 40 percent of global market capitalisation had either decided to use or were actively taking steps to introduce ISSB standards into their domestic regulatory frameworks. **Australia's Treasury Laws Amendment Act 2024** introduced ISSB-aligned disclosures for large companies effective from January 2025. **Across Asia-Pacific, Japan, Indonesia, South Korea, and Singapore** all now require mandatory ISSB-aligned disclosures, with **Thailand** actively exploring adoption. The **trend is consistent**: despite the rollback of federal-level climate disclosure requirements in the United States, mandatory climate disclosure is increasingly becoming a baseline requirement for businesses operating across multiple jurisdictions.

The EU's Corporate Sustainability Reporting Directive occupies fundamentally different conceptual territory from the ISSB framework. The **CSRD mandates double materiality** - requiring companies to report not only on how climate risks affect their financial performance but also on how their own operations affect the environment and society. It also extends **mandatory Scope 3 emissions disclosure**, a requirement notably absent from the SEC's final climate rule adopted in March 2024, which covered only Scope 1 and Scope 2 emissions where material. The SEC rule was stayed almost immediately pending legal challenge and remained in legal limbo through 2025. A systematic mapping of where the CSRD, ISSB, SEC, and California frameworks align and diverge shows that while they **share the four-pillar DNA inherited from TCFD - governance, strategy, risk management, and metrics - they differ critically on materiality thresholds, Scope 3 treatment, assurance standards, and the degree to which sector-specific guidance has been developed.** The practical compliance burden this creates falls unevenly and most heavily on firms least equipped to bear it. Although EU member states were required to transpose the CSRD into national law by July 6, 2024, only eight of 27 member states had done so by August of that year, creating a period of legal uncertainty in which companies could not fully ascertain the consequences of non-compliance across key jurisdictions.

The EU's omnibus simplification initiative, proposed by the European Commission in February 2025, acknowledged this practical reality by proposing to delay and modify the scope of the CSRD's application - a recognition that the standard's ambition, while sound in principle, created an implementation burden that the original timeline made practically unmanageable for a significant share of in-scope firms. A large US multinational with significant EU operations must simultaneously navigate **SEC rules, California's SB 253 and SB 261 disclosure laws, the CSRD and ESRS, and ISSB-aligned rules** in any Asia-Pacific jurisdiction where it operates - each built on partially incompatible data and reporting architecture.

Inconsistent carbon pricing mechanisms represent the third dimension of regulatory fragmentation with direct consequences for investment decisions and capital allocation. There are currently **80 direct carbon pricing instruments** in operation globally, but the effective price range is extreme, spanning near zero to USD 160 per tonne of CO_2 equivalent. **Ten jurisdictions account for 86 percent** of global carbon revenues, and the vast majority of covered global emissions face carbon prices well below the levels that climate economics literature consistently identifies as necessary to drive deep decarbonisation. This inconsistency does not merely create compliance complexity - it undermines the core economic logic of carbon pricing as an investment signal. A firm deciding whether to accelerate capital investment in low-carbon technology is making that decision against radically different price signals depending on where it produces and where its competitors are located.

The cumulative effect of these overlapping forms of fragmentation on corporate investment decisions is not merely theoretical. Empirical research published through CEPR and NBER constructs a measure of carbon price uncertainty analogous to equity market volatility indices and demonstrates statistically significant incentives for firms to delay decarbonisation investments as that uncertainty rises. The broader ESG regulatory rollback at the US federal level following the November 2024 election has reinforced this dynamic materially: the first months of 2025 saw major US financial institutions withdraw from climate coalitions, the **Net Zero Banking Alliance** disbanded, and the **Net Zero Asset Managers Alliance** was substantially revised. These developments highlight the fragility of commitments made without durable policy reinforcement, and the extent to which the widening gap between the EU's continued regulatory deepening and the US federal rollback is creating a structurally fragmented global framework at the worst possible time for climate investment mobilisation.

EVOLUTION OF CLIMATE FINANCE

Section 11

EVOLUTION OF CLIMATE FINANCE

The structural trajectory of climate finance between 2025 and 2035 will be shaped by three intersecting forces: the continued and accelerating growth of sustainable debt instruments, the progressive institutionalisation of climate risk within mandatory financial regulatory frameworks, and the persistent gap between the capital being deployed and the capital that both the science and the economics of the transition require. Each of these forces carries its own internal contradictions that will need to be resolved over the decade ahead.

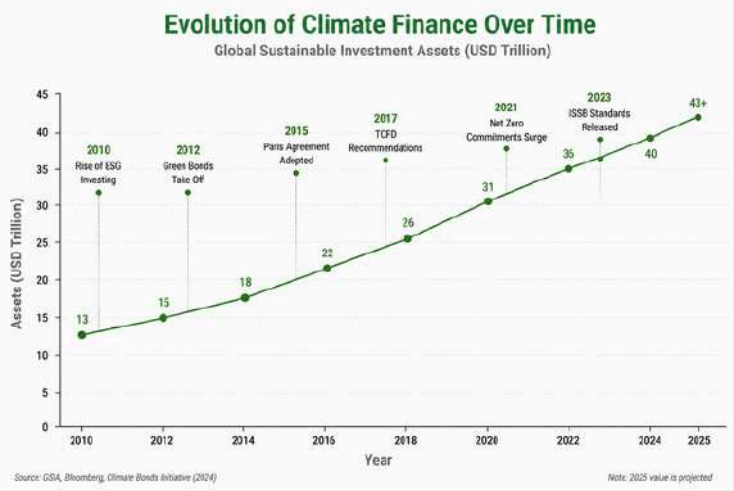
The sustainable debt market crossed a significant threshold in 2024, with cumulative GSS+ volume reaching USD 6.9 trillion by year-end, of which USD 5.7 trillion was found to be aligned with established climate methodologies. USD 1.05 trillion in aligned deals were priced in 2024 alone, representing a record year with 10,331 deals and year-on-year growth of 31 percent. Green bonds remained the dominant segment, accounting for more than half of total aligned issuance at USD 669-670 billion. At COP29, Multilateral Development Banks collectively committed to increasing annual climate financing to USD 120 billion by 2030 and USD 300 billion by 2035, while supranational issuers drove an 11 percent jump in SSA sustainable debt supply to record levels.

New academic evidence published through CEPR provides the strongest available empirical case that green debt actually changes corporate behaviour rather than simply reflecting firms already on a low-carbon trajectory.

The analysis of corporate green debt issuance between 2017-2018 and 2022-2023 found that within four years of green debt issuance, emissions per unit of income fell by approximately half among green borrowers, while remaining flat for conventional borrowers over the same period. The reductions were primarily driven by declines in direct Scope 1 emissions - suggesting genuine operational change rather than accounting adjustment. The authors estimate that green debt issued between 2018 and 2023 could be associated with 4.5 to 5.7 billion tonnes of carbon reductions by 2025, equivalent to roughly 12 to 15 percent of a single year's global energy-related emissions. Despite these volumes, green bonds still account for only 3 percent of the global bond market, constrained by regulatory complexity, high issuance costs, inconsistent green definitions across jurisdictions, and a narrowing or disappearing greenium in many market segments. The institutionalisation of climate risk within regulatory frameworks represents what may be the most durable structural development of the research period. The TCFD disbanded formally on October 12, 2023, with the FSB transferring responsibility for monitoring disclosure progress to the IFRS Foundation from 2024 onward - a transfer that signals the completion of the voluntary-to-mandatory transition in the leading economies.

As of June 2025, 36 jurisdictions had adopted or were finalising steps to adopt ISSB standards. The tension with the political rollback in the United States is significant: US financial institutions accounted for only 0.1 percent of global green bond volume in early 2025, and issuance fell dramatically amid widespread greenhushing - the deliberate avoidance of green labelling for political or reputational reasons.

The ESG investment category itself faces a reckoning with quality and credibility in the period ahead. Some governments - including Canada, Switzerland, South Korea, the US, and certain EU member states - rolled back or paused ESG policies in 2025, while China and the UK advanced ISSB climate disclosure implementation. Despite these headwinds, global sustainable assets under management grew to USD 3.2 trillion, suggesting that institutional demand is proving more durable than political noise, but the quality and ambition of integration vary enormously across institutions. The decade ahead will require a sharper distinction between institutions conducting genuine, forward-looking climate risk analysis - including physical risk exposure mapping, transition risk modelling, and climate value-at-risk frameworks - and those maintaining ESG labels as reputational positioning without substantive analytical content.



Expansion of Carbon Markets

The 2025-2035 decade will witness the most consequential expansion of compliance carbon markets since the EU ETS began operating in 2005. This is not primarily a story about the voluntary market - where a structural credibility crisis has forced a fundamental reset - but about the globalisation of mandatory carbon pricing as a permanent feature of economic governance across the major emitting economies.

Carbon pricing now covers 28 percent of global greenhouse gas emissions, up from 24 percent in 2024 - itself a step change from the 12 percent coverage of a decade earlier. There are 80 direct carbon pricing instruments operating worldwide covering jurisdictions representing nearly two-thirds of global GDP. Carbon pricing revenues reached over USD 100 billion in 2024, more than three times the revenue generated in 2013. The coverage of power sector emissions specifically has crossed 50 percent. Middle-income economies including Brazil, India, and Türkiye are at varying stages of implementing domestic ETSs: India released a draft framework for its Carbon Credit Trading Scheme in late 2024, while Brazil's national ETS legislation passed its first committee review in early 2025.

The single most consequential development in the global expansion of carbon pricing is the extension of China's national ETS beyond the power sector. Expanded in 2025 to include cement, steel, and aluminium, the system brought over 1,300 new enterprises and an estimated 3 billion tonnes of additional emissions under regulation, increasing total market coverage to more than 60 percent of China's national CO_2 emissions - making China's ETS alone responsible for approximately 15 percent of global emissions from fossil fuel combustion.

The EU ETS traded 13.7 billion tonnes of CO_2 equivalent across 4.7 million transactions in 2024, achieving a 50 percent emissions reduction relative to 2005 levels. The design of China's system continues to limit its price signal effectiveness: the absence of a total absolute cap and the intensity-based allocation mechanism create a structural risk of allowance oversupply that depresses prices below levels sufficient to incentivise deep decarbonisation investments.

The finalisation of Article 6 rules at COP29 in Baku in November 2024 represents the most important development for international carbon market architecture since the Kyoto Protocol's Clean Development Mechanism. Article 6.2 enables bilateral carbon trading agreements between sovereign states. Article 6.4 establishes a centralised UN-supervised carbon credit registry with standardised verification and prevention of double-counting - providing institutional foundations for a genuinely international carbon market that had been discussed since the Paris Agreement was adopted in 2015 but had not previously been given operational form. The consensus reached at COP29 on the Paris Agreement Crediting Mechanism is expected to blur the boundary between voluntary and compliance markets, with credits carrying corresponding adjustments - preventing double-counting between national inventories and the international voluntary market - already commanding observable price premiums over credits from the same project type that lack such adjustments. Corporate participation in carbon markets is deepening as the overlap between voluntary commitments and compliance obligations grows. In the voluntary market, credit issuance increased 12 percent in 2024 compared to 2023, with over 190 million credits issued, while retirements remained steady at 176 million for the fourth consecutive year - a plateau illustrating the limits of demand recovery in the absence of a new wave of corporate commitments. China's domestic voluntary mechanism, the CCER, launched in early 2024 and traded over 2.7 million tonnes by August 2025, supporting offshore wind, solar thermal, methane capture, and afforestation projects - representing an important structural development as the coexistence of a large compliance ETS and a functioning voluntary market within China's domestic architecture mirrors the dual-market structure that has operated in the EU for most of the research period.

Integration of Climate Risk into Financial Systems

The integration of climate risk into the financial system's core infrastructure - its credit rating methodologies, stress-testing frameworks, and capital allocation processes - is the ultimate test of whether the regulatory and market developments of the 2018-2025 research period translate into real-economy outcomes. The evidence at the close of this period is that integration is meaningfully underway but remains systematically incomplete in ways that leave the financial system carrying significant unpriced climate tail risk.The major credit rating agencies have made substantial methodological investments in climate risk integration, but the actual impact on ratings has remained limited relative to the scale of risks being assessed. Moody's uses Issuer Profile Scores and Credit Impact Scores to indicate the relevance of ESG risks across sovereigns, corporates, and structured finance. Fitch has developed Climate.VS, overlaying physical and transition risk data with sector-specific climate vulnerability scores. S&P integrates ESG indicators into sectoral methodologies and conducts forward-looking climate scenario analyses to assess financial resilience. Despite these investments, the share of ratings actually affected by climate risk assessments across the Eurosystem remains below 4 percent, and adjustments where they do occur are typically limited to one rating grade. Transition risks have proven more tractable than physical risks for standard credit models, with

manufacturing, construction, and trade most affected. The ECB's minimum standards for incorporating climate change risk into internal credit assessment systems became applicable at end-2024, representing the first formal supervisory mandate for climate-adjusted credit assessment in a major jurisdiction.

The gap between methodological investment and actual rating impact is well documented from the market side. At S&P, physical climate and climate transition risks accounted for nearly one-fifth of ESG-related credit rating actions in 2024.

Rated debt in sectors with high or very high overall environmental risk reached USD 4.3 trillion - or 5 percent of total rated debt - more than doubling from USD 2 trillion when the Paris Agreement was unveiled in 2015. Yet current methodologies, with their limited focus on near-term and visible ESG risks, continue to overlook longer-term impacts, leaving investors exposed to financial shocks that current ratings do not adequately signal. S&P's scenario analysis found that companies in five major carbon-intensive sectors faced a 31-54 percent downgrade risk in an orderly energy transition by 2050, rising to 53-74 percent in a disorderly transition - a material mispricing of climate tail risk embedded in investment-grade debt held by institutional investors worldwide.

Climate stress testing in banking has followed a trajectory from exploratory exercises toward progressively formalised supervisory expectations, though significant methodology gaps remain. The core challenge is translating macro-level integrated assessment model outputs into financially tractable counterparty-level credit risk assessments. Bank supervisors - the ECB prominently among them - expect banks to model physical risk impacts on counterparties at varying degrees of granularity without prescribing any particular model, but the absence of generally accepted industry-standard models remains a major obstacle. The proposed methodology for incorporating physical risk into credit risk modelling uses an extension of the one-factor Vasicek model, integrating climate damage functions with sector-specific vulnerability parameters - a starting point that remains to be adopted at scale. The Federal Reserve Board's exploratory climate risk exercise with six of the largest US banks established a methodological baseline that is likely to inform future supervisory mandates even under the current federal rollback.

At the institutional investor level, the UN-convened Net-Zero Asset Owner Alliance grew to 87 signatories across 19 countries with USD 9.2 trillion in assets under management by mid-2025, with its fourth edition Target-Setting Protocol extending coverage to the entirety of signatories' private assets. However, comprehensive, validated targets aligned with 1.5°C pathways remain rare, and just 14 percent of financial institutions by AUM had credible fossil fuel exclusion policies as of 2024. The withdrawal of major financial institutions from climate coalitions since late 2024, the disbandment of the Net Zero Banking Alliance, and revisions to the Net Zero.

Asset Managers Alliance all highlight how political headwinds in major markets are producing institutional fragmentation precisely at the moment when scale and coordination are most needed.

The geographic distribution of climate finance is arguably the most critical and least addressed systemic gap in the entire climate finance architecture. While global clean energy investment topped USD 2 trillion in both 2024 and 2025, emerging and developing economies outside China received less than 15 percent of that capital - despite accounting for approximately one-third of new renewable energy additions globally and representing the primary source of future emissions growth. Emerging and developing economies need approximately USD 1.3 trillion in annual clean energy investment by 2035, including USD 375 billion in equity. In 2024, equity accounted for only USD 100 billion of the USD 330 billion invested in these markets - meaning equity investment must scale roughly fourfold by 2035. This gap is not explained by underlying economic fundamentals; it reflects risk perception, currency exposure, institutional unfamiliarity, and the absence of the standardised regulatory frameworks that large institutional investors require to deploy capital efficiently at scale. The New Collective Quantified Goal on Climate

Finance agreed at COP29 sets a target of USD 300 billion per year for developing countries from developed countries by 2035, and USD 1.3 trillion in total from all sources - figures that represent both the ambition of the international consensus and the substantial distance still to travel.

GLOSSARY

Section 12

GLOSSARY

Additionality. A core requirement for carbon credits, meaning the emissions reductions represented by a credit would not have occurred in the absence of the carbon market revenue generated by the project. A credit lacking additionality offers no genuine environmental benefit.

Article 6 (Paris Agreement). The provision of the Paris Agreement governing international carbon market mechanisms, comprising bilateral trading of Internationally Transferred Mitigation Outcomes (Article 6.2) and a UN-supervised centralised crediting mechanism (Article 6.4, the Paris Agreement Crediting Mechanism).

Asymmetric Information. A market condition in which one party to a transaction possesses materially more relevant information than the other. In climate finance, firms typically hold greater knowledge of their climate risk exposure than investors, potentially distorting asset pricing.

Cap-and-Trade System (ETS). A market-based regulatory instrument that sets a fixed aggregate ceiling on greenhouse gas emissions across regulated entities, distributes or auctions tradable allowances up to that cap, and permits participants to buy and sell allowances. Also referred to as an Emissions Trading System (ETS).

Carbon Credit. A transferable instrument certified by a recognised standard to represent one metric tonne of carbon dioxide equivalent (tCO_2e) of emissions reduced, avoided, or removed from the atmosphere. Used primarily in voluntary carbon markets.

Carbon Risk Premium. The additional return demanded by investors to compensate for the financial uncertainties associated with a firm's exposure to carbon-intensive operations, including transition risk, physical risk, and regulatory risk.

Carbon Tax. A direct government-imposed levy on greenhouse gas emissions, set at a fixed price per tonne of CO_2 equivalent. Unlike cap-and-trade systems, carbon taxes provide price certainty but not quantity certainty.

CBAM (Carbon Border Adjustment Mechanism). An EU regulatory instrument applying a carbon cost to imports from countries with less stringent climate policies, designed to prevent carbon leakage and ensure competitive neutrality between EU producers subject to carbon pricing and foreign competitors that are not.

Clean Development Mechanism (CDM). A flexibility mechanism established under the Kyoto Protocol allowing developed countries (Annex I) to fund emissions reduction projects in developing countries and earn Certified Emission Reductions (CERs) counted toward their own targets. Superseded by the Article 6.4 mechanism under the Paris Agreement.

Cost of Capital. The minimum required rate of return that a firm must earn on its investments to satisfy its financiers. It comprises the cost of equity and the cost of debt, weighted by their respective proportions in the firm's capital structure (WACC). Climate disclosure quality is hypothesised to reduce the cost of capital by lowering perceived risk.

Cost of Equity. The return required by equity investors to compensate for the risk of holding shares in a company. Estimated using models such as CAPM. In this research, it is used as the primary dependent variable for assessing the financial impact of climate disclosure quality.

CSRD (Corporate Sustainability Reporting Directive). The European Union's mandatory sustainability reporting framework, which entered into force in January 2023, replacing the Non-Financial Reporting Directive. It requires in-scope companies to report under the European Sustainability Reporting Standards (ESRS), applying the double materiality principle.

Cumulative Abnormal Return (CAR). In event study methodology, the sum of abnormal stock returns over a defined event window around a particular disclosure or regulatory event. It measures the total market reaction to that event.

Double Materiality. A disclosure concept, central to the EU CSRD/ESRS framework, requiring companies to report both on how sustainability factors affect their financial performance (financial materiality) and on how their own operations affect the environment and society (impact materiality). Distinct from the single materiality standard used by the ISSB.

ESG (Environmental, Social, Governance). A framework for evaluating non-financial factors relevant to a company's long-term performance and risk profile. Environmental factors include emissions and climate risk; social factors include labour practices; governance factors include board structure and executive accountability.

GLOSSARY

ESRS (European Sustainability Reporting Standards). The detailed technical standards, developed by EFRAG and adopted by the European Commission, that in-scope companies must apply when preparing reports under the CSRD. They operationalise the double materiality principle across twelve sector-agnostic thematic areas.

Event Study Methodology. An empirical research technique measuring the statistical impact of a specific event on asset prices by comparing actual returns against a counterfactual normal return estimated from a pre-event window. Used in this study to assess market reactions to climate disclosure announcements.

Fixed Effects Model. A panel data regression specification that controls for unobserved, time-invariant characteristics of individual firms by including firm-specific intercepts, allowing the analysis to isolate the effect of within-firm changes in climate disclosure quality on financial outcomes.

Greenwashing. The practice of overstating, misrepresenting, or selectively disclosing environmental credentials to create a misleading impression of strong sustainability performance. A key risk associated with voluntary and inconsistent climate disclosure frameworks.

ICVCM (Integrity Council for the Voluntary Carbon Market). An independent governance body established to set and enforce quality standards for voluntary carbon credits, operationalised through the Core Carbon Principles (CCPs). As of 2025, it had approved seven crediting programmes and 36 methodologies.

IFRS S1 / IFRS S2. The inaugural sustainability disclosure standards issued by the ISSB in June 2023. IFRS S1 covers general requirements for sustainability-related financial disclosures; IFRS S2 addresses climate-specific disclosures, building on TCFD's four-pillar framework and incorporating SASB industry metrics.

Information Asymmetry. See Asymmetric Information.

Internal Carbon Price. A shadow price applied voluntarily by a company to its own greenhouse gas emissions, used in internal investment appraisals and procurement decisions to embed the expected future cost of carbon into business decision-making. Microsoft and Infosys are cited in this study as prominent practitioners.

ISSB (International Sustainability Standards Board). An independent standards body established by the IFRS Foundation at COP26 in 2021 with the mandate to develop a globally consistent baseline for sustainability and climate-related financial disclosures. Issued IFRS S1 and S2 in June 2023.

ITMOs (Internationally Transferred Mitigation Outcomes). Units representing emissions reductions or removals traded between countries under Article 6.2 of the Paris Agreement. Subject to corresponding adjustments to prevent double-counting against both the transferring and acquiring country's NDCs.

MRV (Monitoring, Reporting, and Verification). The system of procedures ensuring that emissions data and claimed reductions reported under carbon markets or climate frameworks are accurately measured, transparently reported, and independently verified. Foundational to the environmental integrity of both compliance and voluntary carbon markets.

NDC (Nationally Determined Contribution). A country's self-determined plan, submitted under the Paris Agreement, setting out its intended emissions reduction targets and climate adaptation measures. The Paris Agreement's carbon market provisions are designed to help countries meet their NDC commitments cost-effectively.

NGFS (Network for Greening the Financial System). A coalition of central banks and financial supervisors committed to managing climate risk in the financial sector, providing scenario frameworks for climate stress testing and advocating for the integration of climate risk into supervisory mandates.

Paris Agreement. The landmark international climate treaty adopted at COP21 in December 2015, committing signatory nations to limiting global average temperature increases to well below 2°C above pre-industrial levels, and pursuing efforts to limit warming to 1.5°C. Provides the overarching policy framework within which climate disclosure and carbon markets have developed.

Physical Climate Risk. Financial risks arising from the direct physical impacts of climate change, including damage to assets and operations from extreme weather events (acute physical risk) and long-term shifts such as sea-level rise, temperature increases, and precipitation changes (chronic physical risk).

Pigouvian Tax. A corrective tax, theorised by economist Arthur Cecil Pigou, set equal to the marginal social cost of a negative externality. Carbon taxes are a direct application of Pigouvian taxation to the problem of greenhouse gas emissions.

CONCLUSION

Section 13

CONCLUSION

12.1 SUMMARY OF KEY FINDINGS

This research has examined the relationship between climate disclosure, carbon markets, and financial market outcomes across the period 2018 to 2025 - a period that has compressed decades of expected regulatory and market evolution into seven years. The findings converge on a core conclusion: climate risk is now a material and measurable financial variable, and the quality of climate disclosure directly shapes how that risk is priced by capital markets.

The theoretical framework developed in Section 3 demonstrated that climate risks transmit to financial markets through at least four distinct channels: regulatory and policy transition, technological disruption, physical climate events, and litigation and liability. Each of these channels operates on both expected cash flows and discount rates simultaneously, producing valuation effects that are non-linear and, in some cases, structurally irreversible. The valuation model presented in Section 3.2.4 illustrated this concretely: under identical expected cash flows, the difference between strong and poor climate disclosure produces a measurable divergence in firm value through the discount rate channel alone.

The empirical literature reviewed in Sections 2 and 6 largely supports the hypotheses proposed in Section 1.2.2. Higher-quality climate disclosure is consistently associated with lower costs of equity and debt, reflecting reduced information asymmetry and lower perceived risk. Poor or inconsistent disclosure is associated with higher required returns, consistent with investors demanding a risk premium for unresolved uncertainty. Disclosure functions as a credible signalling mechanism, and its market effects are most pronounced for firms with high carbon intensity and high institutional ownership.

The regulatory landscape examined in Section 4 confirmed that the voluntary disclosure model has reached its structural limits. The TCFD framework was pivotal in building a common vocabulary and demonstrating investor demand for climate information, but the heterogeneity of outputs under voluntary regimes rendered cross-firm comparison practically infeasible for most investors. The ISSB's IFRS S1 and S2 standards, the EU's CSRD, and sub-national frameworks such as California's SB-253 represent the shift toward a mandatory baseline - one that is expanding across jurisdictions despite the US federal rollback.

Carbon markets, examined in Sections 5 and 11, have undergone their own structural transformation. Compliance markets now cover approximately 28 percent of global emissions, and the finalisation of Article 6 rules at COP29 in late 2024 has provided the institutional architecture for genuine international carbon trading. The voluntary market experienced a severe credibility crisis during 2022 to 2024, driven by systemic integrity failures in project-based credits, but the market is bifurcating around quality, with removal credits and CCP-approved instruments commanding significant premiums. These dynamics are beginning to have measurable effects on asset pricing and capital allocation.

The case studies in Section 8 illustrated these dynamics in practice. Tesla's carbon credit revenues demonstrated how regulatory design creates asymmetric financial advantage for first-movers. BP's 2020–2025 cycle showed how formal disclosure compliance and substantive capital allocation alignment are not the same thing, and that disclosure frameworks alone cannot resolve this gap. Microsoft's internal carbon pricing mechanism illustrated the most developed corporate application of shadow pricing as a governance tool. Adani Green Energy highlighted the risk of conflating ESG ratings with governance quality. Infosys illustrated both the benchmark-setting possibilities and the methodological limits of carbon neutrality claims.

12.2 SYNTHESIS: ANSWERING THE CORE RESEARCH QUESTIONS

The three core research questions posed in Section 1.2.1 can now be answered with reference to the evidence accumulated across the study.

On whether climate disclosure materially affects financial market outcomes, the evidence is affirmative. Event studies consistently document abnormal stock returns around climate disclosure announcements, with the direction and magnitude dependent on disclosure quality, carbon intensity, and ownership structure. Companies with higher-quality disclosure demonstrably achieve lower costs of equity and debt. The cross-sectional evidence shows that carbon-intensive sectors have experienced systematic valuation penalties relative to low-carbon peers, and this gap has widened over the research period.On how disclosure quality influences investor behaviour and asset pricing, the evidence points to a shift from peripheral ESG reporting to core valuation input. Investors are increasingly using firm-specific climate risk data rather than aggregated ESG scores, particularly for carbon-intensive sectors. The institutional reallocation documented in Section 6.1.3 away from high-emission firms and toward low-carbon or transition-enabling businesses - is driven in part by the improved quality and comparability of climate data that regulatory developments have produced. On whether disclosure reduces uncertainty in financial markets, the evidence is qualified. Where disclosure is high-quality, standardised, and independently assured, it demonstrably reduces information asymmetry and risk premia. Where disclosure

CONCLUSION

is incomplete, inconsistent, or unverifiable as remains the case across large portions of the global market it does not adequately enable markets to price climate tail risks. The gap between methodological investment in climate risk assessment and actual impact on credit ratings and asset prices, documented in Section 11.3, illustrates the incompleteness of this integration.

12.3 HYPOTHESIS ASSESSMENT

H1 - that higher-quality climate disclosure reduces the cost of capital is supported by the preponderance of the evidence. Studies of S&P 500 firms, European markets, and Indian listed companies consistently find a statistically significant negative relationship between disclosure quality and cost of equity, particularly where disclosure is standardised and independently verified.

H2 - that poor or inconsistent disclosure increases perceived risk and required returns is also supported, though the effect is heterogeneous. The penalty is strongest for high carbon intensity firms under mandatory disclosure regimes, and weakest for firms where investors lack the tools to differentiate disclosure quality from disclosure volume.

H3 - that disclosure serves as a signalling mechanism affecting firm valuation is supported theoretically and empirically. Signalling theory predicts that costly, verifiable disclosures reduce adverse selection, and the event study evidence documents market reactions consistent with investors interpreting disclosure quality as a signal of risk management maturity. The BP case study provides an important qualification: signals can be formally credible while substantively misleading, and markets are not yet uniformly able to distinguish between the two.

12.4 BROADER IMPLICATIONS

This research shows that the global financial system has made significant progress since 2018 in integrating climate risk, but it still faces major unpriced physical and transition risks. Mandatory climate disclosure frameworks across regions like the EU, Asia-Pacific, and North America are expected to improve transparency and information quality if implemented with strong assurance standards and double materiality principles. However, disclosure alone cannot solve the problem because most emissions are still priced too low to encourage deep decarbonisation investment. Going forward, regulators, corporations, and financial markets must address three key gaps: improving disclosure quality over quantity, converting climate risk assessment into real capital allocation decisions, and increasing the flow of capital toward climate solutions. While progress has been made in reducing the disclosure gap between 2018–2025, the other two gaps remain largely unresolved.

12.5 LIMITATIONS AND AREAS FOR FURTHER RESEARCH

This research has several limitations, including inconsistent ESG ratings, limited Scope 3 emissions data, and weak climate disclosure coverage in emerging markets, which reduce the reliability of conclusions. Event study methods mainly capture short-term market reactions, not long-term impacts. Comparing different countries is also difficult because of variations in regulations, financial development, and ownership structures. Future research should focus on better Scope 3 measurement standards, long-term effects of mandatory disclosures, climate risk impacts on credit and bond markets in emerging economies, and whether internal carbon pricing leads to real decarbonisation. The finalisation of Article 6 at COP29 also creates new opportunities to study the impact of international carbon credit markets on climate finance in developing countries.

ANNEXURE

Section 14

ANNEXURE

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