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Climate-Related Financial Risk in Early ESG Integration Models: A Literature Review

Amirah Hanantyas Fatimah[1]

[1] Universitas Muhammadiyah Surakarta, Surakarta, Indonesia

Abstract

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This study examines how early Environmental, Social, and Governance (ESG) integration models addressed climate-related financial risk at a time when climate exposures were not yet fully recognized as material drivers of firm performance. The review synthesizes peer-reviewed evidence to clarify the extent to which early ESG frameworks captured climate-specific vulnerabilities and how these limitations affected financial analysis. Findings show that aggregated environmental indicators and voluntary disclosures often failed to identify transition and physical risks, while financial markets increasingly priced climate information through channels such as carbon emissions, downside risk, and sensitivity to climate news. The article discusses patterns across empirical studies, highlighting challenges in disclosure quality, rating inconsistencies, and the absence of forward-looking climate metrics. Overall, the review finds that early ESG models provided foundational sustainability insights but were insufficient for assessing climate-related financial risk, underscoring the need for more precise and climate-aligned integration tools.

1. Introduction

Climate-related financial risk has become a central concern for global financial markets as climate change intensifies physical hazards and accelerates the transition toward low-carbon economies. These risks influence asset valuations, credit conditions, and firm performance, making climate considerations increasingly relevant to investment analysis. Early Environmental, Social, and Governance (ESG) integration models, however, were developed before climate risk was widely recognized as a financially material factor. As a result, these frameworks often relied on broad environmental indicators and voluntary disclosure metrics that did not fully capture firms' exposure to climate-related shocks. Recent financial research has shown that environmental and sustainability characteristics can significantly influence firm risk profiles, highlighting the limitations of early ESG approaches. Albuquerque et al. (2019) demonstrate that corporate social responsibility affects firm risk and market stability, suggesting that environmental indicators contain useful information yet may be insufficient for assessing climate-specific financial exposures.

A growing body of literature further examines how investors incorporate climate considerations into portfolio decisions. Krueger et al. (2020) find that institutional investors increasingly view climate risk as financially material, yet practical tools for integrating climate-related data into valuation models remain inconsistent. Early ESG systems tended to aggregate environmental practices without distinguishing between general sustainability actions and climate-specific vulnerabilities. Ilhan et al. (2021) show that firms with higher carbon emissions face

significantly greater downside tail risk, indicating that the financial system requires more granular climate metrics to capture both physical and transition risk channels. These findings suggest that early ESG frameworks may underestimate the financial relevance of climate exposures, especially as policy environments, carbon pricing regimes, and technological changes reshape market conditions.

Research on green financing and climate-aligned instruments also reveals structural gaps in early ESG integration. Studies examining green bond issuance show that firms' climate strategies and environmental performance significantly influence their access to sustainable financing (Russo et al., 2021). This evidence reinforces the view that climate-related practices have distinct financial implications not fully reflected in early ESG indicators. Complementary theoretical work by Pástor et al. (2021) demonstrates that investor preferences for sustainability can influence equilibrium returns and risk pricing, suggesting that climate considerations exert a stronger financial impact than early ESG scoring methodologies anticipated. Collectively, these insights underscore the need for more sophisticated and forward-looking ESG integration models that explicitly incorporate climate-related financial risk.

This literature review contributes to ongoing debates by examining how early ESG frameworks addressed climate-related financial risks and identifying where significant gaps remain. By synthesizing empirical findings from peer-reviewed studies, the review clarifies the limitations of early ESG models and highlights the importance of integrating climate science, forward-looking risk indicators, and scenario-based analysis into future ESG methodologies.

2. Literature Review

Early ESG integration models were developed at a time when climate-related financial risk was not yet fully recognized as a distinct and material component of firm valuation. As a result, environmental indicators were often broad and disclosure-driven, creating gaps in the measurement of climate exposure. Schramade (2017) notes that early sustainable investing frameworks relied heavily on qualitative indicators, limiting their ability to capture the financial implications of climate-related shocks. Subsequent research shows that these early models underestimated downside risk associated with emissions intensity and transition pressures. Albuquerque et al. (2019) highlight that environmental practices influence firm risk, but traditional ESG metrics do not differentiate between general sustainability activities and climate-specific exposures, illustrating a methodological weakness in early ESG approaches.

Growing empirical evidence demonstrates that climate-related financial risks materially influence firm performance and investment decisions. Investors increasingly recognize climate variables as financially relevant, yet the tools to integrate climate metrics remain inconsistent. Krueger et al. (2020) find that institutional investors are concerned with both physical and transition risks but face challenges due to inconsistent reporting standards and aggregated ESG scores. Bolton & Kacperczyk (2021) report that firms with high carbon risk experience significantly lower risk-adjusted returns, reinforcing the argument that climate factors need distinct treatment apart from general environmental indicators. Ilhan et al. (2021) further demonstrate that carbon emissions contribute to tail risk,

emphasizing the need for granular, forward-looking metrics. Collectively, these studies show that early ESG frameworks often masked climate risk heterogeneity, limiting investors' ability to assess long-term exposures accurately.

Another strand of literature focuses on capital markets and climate-aligned financial instruments. Research on green bonds suggests that firms with stronger climate strategies gain preferential access to sustainable financing channels. Flammer (2021) finds that corporate green bonds are associated with lower financing costs and improved environmental performance, indicating that markets increasingly price climate-related characteristics. Similarly, Russo et al. (2021) show that green bond issuance responds to firm-level climate strategies, underscoring the financial importance of climate-specific disclosures. Amel-Zadeh and Serafeim (2018) add that investors use ESG information to complement financial analysis, but early ESG datasets lack the precision needed to capture climate-related exposures. These insights collectively highlight structural limitations in early ESG integration models and point toward the need for more climate-focused, science-aligned metrics.

3. Methods

This study employs a systematic literature review approach to evaluate how early ESG integration models addressed climate-related financial risks. The review focuses on peer-reviewed journal articles published between 2017 and 2021 to ensure coverage of the most recent empirical and theoretical developments prior to the emergence of more advanced climate-finance frameworks. Relevant studies were identified using structured searches in major academic databases, including Scopus,

Web of Science, and Google Scholar. Keywords such as "climate-related financial risk", "ESG integration", "carbon risk", "sustainable investing", and "green finance" were used to capture research addressing climate exposures within early ESG models. Only peer-reviewed studies that examined financial implications of environmental or climate-related indicators were included, while conference papers, non-academic reports, and articles lacking empirical or theoretical contributions were excluded.

The screening process followed standard systematic review procedures, beginning with the identification of potentially relevant articles, followed by abstract screening and full-text assessment. For each eligible study, data were extracted on research objectives, methodological approaches, climate-related variables analyzed, and key findings related to the financial relevance of climate indicators. A narrative synthesis method was used to integrate evidence across studies, allowing comparison of how early ESG models conceptualized environmental performance, carbon risk, and sustainability metrics in relation to financial outcomes. This approach enabled the review to identify patterns, gaps, and methodological limitations in early ESG integration frameworks and to assess how effectively these models captured climate-specific financial risks.

4. Results and Discussion

The findings across the reviewed studies indicate that early ESG integration models were not designed to capture climate-related financial risks with sufficient precision. These early frameworks typically relied on aggregated environmental

indicators and voluntary sustainability disclosures, which often overlooked critical distinctions between general environmental performance and climate-specific exposures. Albuquerque et al. (2019) show that corporate environmental behavior has measurable effects on firm risk, yet early ESG systems lacked the granularity needed to isolate climate-related vulnerabilities. Bolton and Kacperczyk (2021) demonstrate that carbon-intensive firms bear higher financing costs and face greater market scrutiny, suggesting that climate exposures have distinct financial consequences not fully reflected in traditional ESG scoring methodologies. These findings highlight the fundamental limitations of early ESG models, which were developed during a period when climate risk had not yet been systematically incorporated into mainstream financial analysis.

Empirical evidence further demonstrates that financial markets increasingly price climate-related information, reinforcing the idea that early ESG frameworks underestimated climate-induced financial risks. Engle et al. (2020) find that firms' sensitivity to climate news, measured through climate beta, significantly predicts stock return reactions to climate-related events. This suggests that climate risk functions as an independent financial risk factor that cannot be adequately captured by general environmental scores. Similarly, Bolton & Kacperczyk (2021) find that firms with higher carbon risk earn lower risk-adjusted returns, implying that transition risk and emissions intensity affect firm value beyond what early ESG metrics captured. Ilhan et al. (2021) add that carbon emissions significantly increase downside tail risk, which is particularly important under scenarios involving extreme weather events or abrupt policy shifts. Together, these studies show that early ESG

integration frameworks masked important climate-specific risk dynamics by treating environmental variables as broad, undifferentiated indicators.

Corporate climate-risk disclosure practices also contributed to weaknesses in early ESG integration. Sautner et al. (2020) observe that voluntary climate disclosures were inconsistent, incomplete, and often lacking forward-looking risk measures. Such disclosure gaps weakened the underlying data used in ESG assessments and made climate-related risk difficult to quantify. Krueger et al. (2020) similarly find that institutional investors recognize climate risk as financially material but struggle with the absence of standardized climate metrics. Climate risk assessment tools during the early ESG period were fragmented and not fully aligned with climate science, which created uncertainty for investors attempting to incorporate climate variables into valuation models. Choi et al. (2020) further show that investor attention to global warming affects stock price movements, demonstrating that market participants respond to climate information even when ESG metrics do not adequately reflect it. These findings collectively illustrate the structural limitations of early ESG frameworks in supporting consistent and reliable climate-risk assessment.

Another important theme emerging from the literature relates to the financial and strategic implications of climate performance. Studies indicate that firms with stronger climate strategies are better positioned to access capital, manage transition risks, and achieve long-term performance advantages. Flammer (2021) finds that corporate green bonds are associated with lower financing costs and enhanced environmental outcomes, suggesting that financial markets reward credible climate

commitments. Russo et al. (2021) reinforce this by showing that green bond issuance is driven by firm-level climate strategies rather than traditional environmental scores. Hao et al. (2021) highlight that climate-aligned policies and low-carbon strategies improve economic and environmental performance in advanced economies, emphasizing the financial benefits of proactive climate actions. These findings demonstrate that climate-specific indicators provide information that early ESG models did not fully incorporate, particularly regarding transition readiness and long-term resilience.

A final issue concerns the reliability of ESG indicators themselves. Gibson Brandon et al. (2021) reveal substantial disagreement among ESG rating agencies, driven partly by inconsistent treatment of environmental and climate variables. Such inconsistencies weaken the reliability of ESG scores for assessing climate risk. Pástor et al. (2021) also find that sustainable investing affects equilibrium returns, suggesting that climate and ESG preferences are increasingly embedded in asset pricing. Together, the evidence indicates that early ESG integration frameworks were valuable for capturing broad sustainability features but inadequate for identifying and quantifying climate-related financial risks. More advanced, climate-specific, and forward-looking models are required to support effective investment decision-making in a rapidly evolving climate-risk landscape.

5. Conclusion

This review shows that early ESG integration models offered useful insights into firm-level sustainability practices but were limited in their ability to capture

climate-related financial risks. Their reliance on qualitative environmental indicators, aggregated ESG scores, and voluntary disclosures meant that critical distinctions between climate-specific exposures and general environmental performance were often overlooked. As climate-related risks became more financially material, these early frameworks proved insufficient for assessing firms' vulnerability to transition pressures, carbon pricing, and physical climate shocks.

The evidence indicates that financial markets increasingly recognize climate risk as a separate and meaningful risk factor. Studies demonstrate that climate-related metrics such as carbon emissions, climate beta, and exposure to climate news have clear implications for stock returns, downside risk, and capital costs. At the same time, inconsistent climate disclosures and substantial disagreement across ESG ratings limited investors' ability to evaluate climate exposures accurately. These findings emphasize that effective climate risk assessment requires more precise, forward-looking tools that are grounded in climate science rather than broad ESG indicators.

Overall, the literature suggests that early ESG integration frameworks provided an important first step toward embedding sustainability considerations into financial analysis, but they did not adequately address the complexity of climate-related financial risks. Moving forward, more robust climate-focused methodologies, standardized disclosures, and science-based metrics are essential for enabling investors and policymakers to understand and manage climate exposures. Strengthening these elements will support more reliable risk assessments, enhance

capital allocation toward resilient firms, and improve the financial system's capacity to navigate the challenges posed by climate change.

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