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The role of ESG-related derivatives in the green transition of capital markets

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Abstract

This study aims to examine the potential contribution of ESG-related derivatives to the green transition of capital markets. We conducted a systematic literature review using the Scopus database, complemented by keyword and co-occurrence analysis with VOSviewer, to map the theoretical structures of sustainable and green finance and to identify key areas where ESG-related derivatives can play a pivotal role. Our findings suggest that these instruments can support the green transition by promoting green and financial innovation, mitigating risks associated with natural resources and renewable energy transition, and facilitating green investments and emissions trading. As policymakers revisit the role of derivatives in sustainability reporting for financial market participants, the importance of ESG-related derivative markets is expected to grow significantly in the near future.

Keywords: Sustainability, sustainable finance, green finance, capital markets, ESG-related derivatives

Journal of Economic Literature (JEL) codes: Q56, G15

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Introduction

As a part of the 2015 United Nations Climate Change Conference, the member states of the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement, which primarily aimed at reducing greenhouse gas (GHG) emissions, mitigating global warming, and addressing the financial implications of these efforts (Horowitz, 2015). Within the framework of the agreement, two primary objectives were established: first, a commitment to limit the annual increase in global average temperature to below 1.5°C; second, numerous signatory countries, including the European Union member states, the United Kingdom, Japan, Canada, the United States, China, South Korea, and New Zealand, have pledged to achieve net-zero GHG emissions from their economies by 2050 (Höhne et al., 2021). While the Paris Agreement represents a global effort, the European Green Deal (2019) constitutes a comprehensive economic, industrial, and environmental policy initiative of the European Union, designed to drastically reduce GHG emissions and achieve climate neutrality (European Commission, 2019). The European Green Deal establishes a broad regulatory framework encompassing sustainability reporting, sustainable finance, facilitating the alignment of economic and environmental objectives (Velte, 2024).

The transition to a sustainable economy requires substantial long-term financing. In this process, the financial services sector serves as a key partner by providing the necessary capital while managing the risks associated with sustainable investments. The green transition on the capital markets requires financial market participants to provide transparent information on sustainability matters to enable educated investment decision making. As a basis of green transition on the capital markets, the ESG framework, which evaluates corporate performance across three dimensions—Environmental (E), Social (S), and Governance (G)—has become a fundamental tool in sustainability-related financial decision-making (Van Dureen et al., 2016). Next to that, regulatory drivers like the Sustainable Finance Disclosure Regulation (SFDR) and the EU taxonomy regulation protected investors against green washing concerning financial products.

Over the past decade, companies have widely employed derivative instruments for risk management, arbitrage, and speculation. In a 2020 report, the U.S. Commodity Futures Trading Commission (CFTC) stated that "derivatives markets can be part of the solution" in addressing climate change. Despite the increasing relevance of ESG-related derivatives, prevailing policy and regulatory frameworks continue to categorize them primarily as instruments for risk management. This regulatory stance has impeded financial market participants from incorporating ESG-related derivatives into the principal adverse impact (PAI) indicators. Furthermore, the asymmetrical treatment of these instruments with respect to the key performance indicators (KPIs) outlined in the EU Taxonomy presents an ongoing methodological and regulatory challenge. The new regulatory technical standard issued by the European Supervisory Authorities (ESAs) provides clarification on the treatment of derivatives, raising expectations that the broader regulatory framework will align with the updated guidance.

Our research aims to scrutinize how ESG-related derivatives can contribute to the green transition of capital markets. After the systematic review of the literature, we found that the main theoretical structures of green and sustainable finance include green and financial innovation, natural resources, renewable energy transition, green investments, and emission trading where ESG-

related derivatives can play a pivotal role and facilitate the green transition. Our research seeks to contribute to the ongoing discourse on the treatment of derivatives in sustainability reporting, particularly as policymakers reconsider the regulatory framework of sustainable finance.

Our paper proceeds as follows: First we introduce policy and regulatory drivers for financial market participants. Next, we elaborate on the role of ESG-related derivatives in the green transition. After that we map the theoretical structure of green and sustainable finance and identify the key areas where ESG-related derivatives can play a crucial role. Last, our paper concludes how significant ESG related derivatives can become in the future.

Derivatives in sustainability reporting for financial market participants

To encourage investments in sustainable activities, the European Union has introduced two key regulations: the Sustainable Finance Disclosure Regulation (SFDR, 2019/2088/EU) and the EU Taxonomy Regulation (2020/852/EU). The primary aim of these regulations is to improve the transparency and comparability of ESG investment products, mitigate the risk of greenwashing, and facilitate the redirection of capital flows toward sustainable economic activities. The regulatory framework for sustainable finance also encompasses sector-specific policies for financial market participants, such as MiFID II, the Alternative Investment Fund Managers Directive (AIFMD II), and the Benchmark Regulation.

Table 1. introduces the treatment of derivatives in the regulatory framework of sustainable finance. The SFDR requires financial market participants and financial advisers to disclose how they integrate sustainability risks that could affect the value and return of investments (“outside-in” effect) and how their investments may negatively impact the environment and society (“inside-out” effect). Disclosures must be provided both at the firm level and for individual financial products. Under the SFDR, financial products are classified into three categories. Dark green products (Article 9) have a sustainable investment objective, light green products (Article 8) promote environmental or social characteristics, while non-green products (Article 6) do not promote any ESG-related objectives. As policy makers revisit the regulation, Platform on Sustainable Finance proposed a new categorization framework for investment products identifying sustainable, transition, ESG collection and unclassified products. The regulation applies to investment funds, insurance products, pension products, and portfolio management services. At the entity level, the SFDR mandates the disclosure of principal adverse impact (PAI) indicators, which reflect the negative effects of investment decisions on various sustainability matters. Although derivatives are not directly subject to the regulation, financial market participants must explain how derivatives contribute to achieving sustainable investment objectives.

The EU Taxonomy Regulation amended the SFDR by introducing criteria that enable investors to assess the sustainability of economic activities. It defines six environmental objectives: climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. Additionally, it sets out four overarching conditions that an economic activity must meet to qualify as environmentally sustainable. The Taxonomy Regulation establishes different key performance indicators (KPIs) for various financial sectors. Credit institutions are required to disclose their Green Asset Ratio (GAR), while asset managers and insurance companies must report their Green Investment Ratio

(GIR). Derivatives are excluded from the numerator of these KPIs, reflecting their primary role in mitigating counterparty risk rather than financing specific assets or economic activities. However, derivative exposures are included in the denominator of financial institutions' green ratios, as they contribute to the total assets that the ratios are intended to cover.

In December 2023, the European Supervisory Authorities published a draft on the amendment of the SFDR in which they proposed modifications to existing environmental and social indicators to provide a more comprehensive view of the adverse impacts of investment decisions. Financial market participants have to disclose GHG emissions reduction targets, including detailed information on methodologies, intermediary targets, and progress tracking. The draft clarifies the inclusion of derivatives in PAI calculations, requiring conversion to economic exposure equivalents to ensure accurate representation of their impact. This approach ensures that the impact of derivatives on sustainability factors is accurately represented, preventing potential circumvention of PAI reporting through derivative transactions. Net short exposures achieved through derivatives cannot be used to offset long positions. This measure prevents the artificial inflation of sustainability metrics by using derivatives to create net short positions that could otherwise reduce the apparent exposure to non-sustainable investments.

Table 1. Treatment of derivatives in the regulatory framework of sustainable finance

Regulation	Year	Treatment of derivatives
Sustainable Finance Disclosure Regulation (2019/2088/EU)	2019	Derivatives are not subject to the regulation.
EU Taxonomy Regulation (2020/852/EU)	2020	Derivatives are excluded from the numerator and included in the denominator of KPIs
Draft Regulatory Technical Standards on the review of PAI and financial product disclosures in the SFDR Delegated Regulation	2023	Inclusion of derivatives in PAI Calculations via economic exposure equivalents considering net exposures. Introducing floor to zero to exclude net short positions.

The International Swaps and Derivatives Association (ISDA) has articulated a comprehensive position on the treatment of derivatives under the Sustainable Finance Disclosure Regulation (SFDR) and the EU Taxonomy Regulation, as outlined in the European Supervisory Authorities' (ESAs) Regulatory Technical Standards (RTS). ISDA advocates for the development of a unified, industry-wide methodology to assess and report the sustainability characteristics of derivatives, emphasizing that premature implementation of mandatory methodologies could lead to inconsistencies. It critiques the current regulatory approach, particularly the asymmetric treatment whereby derivatives are included in the denominator but excluded from the numerator of sustainability-related key performance indicators (KPIs), arguing that this misrepresents the true economic exposure provided by derivatives. To address this, ISDA proposes the adoption of a delta-based exposure measurement, a method commonly used in risk management to capture the sensitivity of derivatives to changes in the price of the underlying assets. In terms of asset

classes, equity and bond derivatives should be included in sustainability assessments, proportional to the exposure they provide to the underlying assets. Interest rate (IR) and foreign exchange (FX) derivatives, typically used for hedging purposes and linked to underlyings not directly associated with sustainable economic activities, should be excluded from both the numerator and denominator of sustainability KPIs to prevent misleading representations (ISDA, 2023).

Table 2. summarizes the categorization of ESG-related derivatives. ESG-related derivatives have emerged as vital tools to support the transition to a sustainable economy. These products allow market participants to manage risks, finance sustainability initiatives, and align their portfolios with ESG objectives. Based on the ISDA report, ESG derivatives can be broadly categorized into several types, each serving distinct purposes. Sustainability-linked derivatives (SLDs) are customized derivatives—such as interest rate swaps, cross-currency swaps, and FX forwards—where the terms are linked to the achievement of specific ESG performance targets. If a counterparty meets predetermined sustainability key performance indicators (KPIs), favorable pricing adjustments or other financial incentives are applied. Conversely, failure to meet targets could trigger penalties, such as funding dedicated to green initiatives. These instruments promote corporate accountability for sustainability goals while allowing traditional risk management. ESG-related credit derivatives include ESG-screened credit default swap (CDS) indices, like the iTraxx MSCI ESG Screened Europe Index. They allow participants to hedge credit risk exposure to entities with superior ESG credentials or gain investment exposure to companies that meet ESG screening criteria. This structure integrates ESG considerations directly into traditional credit risk management practices. ESG-related exchange-traded derivatives consists of futures and options contracts based on ESG equity indices, such as the S&P 500 ESG Index Futures and STOXX Europe 600 ESG-X Futures. Investors use these products to hedge or adjust exposure to ESG-aligned equity benchmarks efficiently, without the need to trade the underlying equities individually. They offer a liquid, scalable solution for implementing ESG strategies.

Table 2. Categorization of ESG related derivatives

Category	Description	Products	Use-cases
Sustainability-linked derivatives	Derivatives with terms (e.g., pricing, payoff) linked to the achievement of predefined sustainability or ESG targets.	Interest rate swaps (IRS), cross-currency swaps, and FX forwards, linked to ESG performance targets.	Financial incentives or penalties based on achievement of sustainability KPIs. Redirecting proceeds to climate action projects if targets are not met.
ESG-related credit derivatives	Credit default swap indices referencing companies with ESG characteristics or performance criteria.	ESG-screened credit default swap (CDS) indices	Hedging credit risk exposure to companies based on ESG profiles. Gaining exposure to a basket of higher ESG-rated corporates.
ESG-related exchange-traded derivatives	Derivatives traded on exchanges, linked to listed ESG-related equity indices.	Futures and options on ESG equity indices	Hedging ESG-aligned investment portfolios. Implementing ESG strategies efficiently without buying underlying stocks.
Emission trading derivatives	Derivatives linked to carbon allowances or other emissions trading schemes.	Futures, forwards, and options based on carbon allowances	Managing exposure to carbon price risks. Compliance with cap-and-trade programs. Participation in voluntary carbon markets for corporate social responsibility goals.
Renewable energy and fuels derivatives	Derivatives referencing renewable energy (e.g., wind, solar) or renewable fuel prices.	Power Purchase Agreements (PPAs) (both physical and virtual). Renewable Energy Certificate (REC) futures. Wind Index futures, Renewable Identification Numbers (RINs) futures, Low Carbon Fuel Standard (LCFS) futures.	Hedging risks related to renewable energy production and price volatility. Supporting renewable energy project financing. Meeting corporate sustainability commitments.
Catastrophe and weather-linked derivatives	Derivatives tied to climate-related events (e.g., hurricanes, floods) or specific weather conditions.	Catastrophe swaps, pandemic risk swaps, weather index-based futures/options.	Hedging financial risks from natural disasters (e.g., hurricanes, earthquakes). Managing losses from extreme weather impacting business operations (temperature, wind, precipitation metrics).

Source: ISDA executive summary (2021)

Emissions trading derivatives involve futures, forwards, and options based on carbon emission allowances (e.g., EU Emissions Allowances). They serve both compliance and voluntary carbon markets, enabling companies to hedge carbon price risks or meet regulatory requirements under cap-and-trade programs. Such products play a critical role in the global effort to manage climate risks and support net-zero ambitions. Renewable energy and renewable fuels derivatives include virtual and physical Power Purchase Agreements (PPAs), Renewable Energy Certificate (REC) futures, and renewable fuel-related futures such as Renewable Identification Numbers (RINs) and Low Carbon Fuel Standards (LCFS) futures. These derivatives help companies hedge risks associated with renewable energy generation and price volatility. Additionally, they support the financing and expansion of renewable energy infrastructure by providing predictable revenue streams for project developers. Catastrophe and weather derivatives consist of catastrophe swaps, weather-indexed futures, and options enable companies to hedge financial risks arising from extreme weather events or natural disasters. These instruments are particularly valuable for businesses vulnerable to weather variability, such as agriculture, energy, and construction sectors. They allow for better resilience planning in the face of climate change-induced weather extremes. In summary, ESG-related derivatives provide essential mechanisms for hedging, investment, and sustainability integration, fostering the growth of sustainable finance markets. Their development reflects an ongoing effort to align financial products with broader environmental and social objectives.

Research question and research gap

When examining the regulatory framework of sustainable finance, the treatment of derivatives emerges as a controversial issue for both financial market participants and policymakers. The current framework treats derivatives asymmetrically, restricting their use for hedging positions. Policymakers often view derivatives primarily as instruments for risk mitigation or speculation, detached from real economic activities. However, ESG-related derivatives have the potential to support the green transition of capital markets in several ways, and their associated markets are experiencing rapid growth. In addressing Research Question RQ1, our study aims to explore how ESG-related derivatives can contribute to the green transition of capital markets.

RQ1: How can ESG-related derivatives contribute to the green transition of capital markets?

As the role of ESG-related derivatives becomes increasingly significant and policymakers revisit the sustainable finance regulatory framework, our research provides valuable insights into how financial market participants can leverage ESG-related derivatives to advance sustainability objectives and capitalize on emerging opportunities.

Research methodology

To deepen our understanding of the theoretical frameworks underpinning the role of ESG-related derivatives in the green transition of the capital markets, we conducted a comprehensive systematic literature review using the Scopus database. The methodological approach applied in our review is illustrated in Figure 1. Our research process began with the careful selection of keywords and the definition of screening criteria to ensure a focused and relevant inquiry. Specifically, we employed the search string "(green AND finance*) OR (sustainabl* AND finance*)" and restricted the results to English-language journal articles within the fields of business, management, and accounting, as well as economics, econometrics, and finance. To capture literature published after the Paris Agreement, we further limited the timeframe to publications between 2016 and 2025. This structured search yielded 4,530 documents and identified 15,121 unique keywords related to sustainable and green finance. To further explore the theoretical structures within the field, we conducted a keyword and co-occurrence analysis using VOSviewer, following established methodological approaches (Feng et al., 2017; Paltrinieri et al., 2023; Zupic & Čater, 2015). Prior to analysis, we implemented a rigorous data standardization process that included setting an initial relevancy threshold of 25 keyword occurrences. We then refined the dataset by eliminating acronyms, harmonizing singular and plural forms, merging closely related terms, and filtering out irrelevant keywords. Following this preliminary refinement, we increased the relevancy threshold to 30 occurrences to ensure that only the most significant keywords were retained. This iterative process allowed us to delineate a clear and explicit theoretical structure. Ultimately, our analysis identified 111 highly relevant keywords, each appearing at least ten times within the dataset. These keywords were grouped into five thematic clusters, each comprising a minimum of three interrelated terms, thereby revealing key conceptual groupings within the theoretical field of sustainable and green finance.

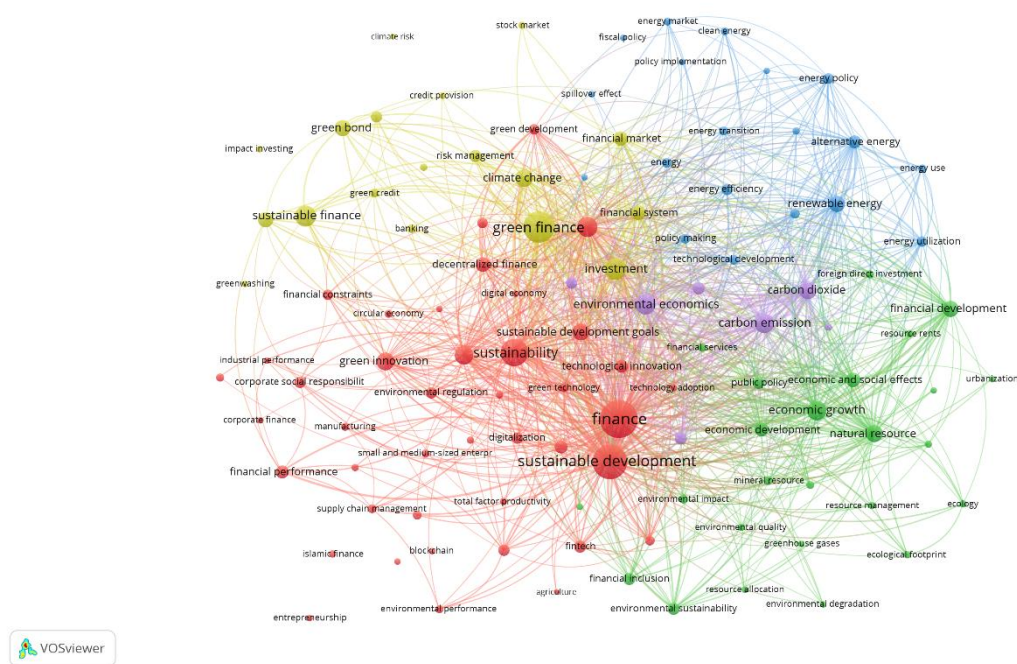
Figure 1.: Research methodology

Systematic literature review	Sample identification	<ul style="list-style-type: none"> Source: Scopus database Search criteria: (green AND finance*) OR (sustainabl* AND finance*) 	4530 documents, 15121 keywords
	Screening	<ul style="list-style-type: none"> Document type: English journal articles Subject area: Business, management and accounting, Economics, econometrics and finance Period: 2016 to 2025 	
	Keyword standardization	<ul style="list-style-type: none"> Elimination acronyms, Unification of singular to plural keywords, Combination of closely related keywords Exclusion of irrelevant keywords Relevancy threshold of 25 occurrences 	111 keywords, 5 clusters
	Keyword and co-occurrence analysis	<ul style="list-style-type: none"> Relevancy threshold of 30 occurrences Minimum cluster size of 3 	

ESG-related derivatives in the theoretical structures of sustainable and green finance

To explore the theoretical structures associated with ESG-related derivatives, we conducted a co-occurrence analysis, the results of which are visualized in Figure 2 as a network map. This visualization illustrates the interconnectedness of key concepts within the field, offering insights into the dominant themes shaping sustainable and green finance. In the map, the size of the nodes reflects the frequency of keyword occurrences, while the thickness of the links indicates the strength of relationships between keywords, highlighting the most influential connections within the dataset. The network comprises 111 nodes and 4,421 links, with a total link strength of 39,369, demonstrating a dense and intricate web of interrelated concepts in green and sustainable finance. Through this analysis, we identified five distinct theoretical clusters including green and financial innovations, natural resources, renewable energy, green investments, emission trading. By visualizing these theoretical structures, our analysis provides a comprehensive understanding of the key dimensions influencing the green transition of the capital markets and allow us to identify key areas where ESG-related derivatives can play a pivotal role.

Figure 2. Co-occurrence analysis



Source: Scopus and VOSviewer

Table 3. represents the keyword analysis concerning the theoretical structures of green and sustainable finance. To introduce the potential contribution of the ESG-related derivatives, we summarize the literature which highlights the application of derivatives for each cluster. Green financial innovation cluster emphasizes how ESG-related derivatives can foster green innovation. Billio et al. (2022) address new instruments like sustainability-linked swaps that are reshaping financial markets. The authors argue that ESG integration needs to go beyond compliance and foster transformational change. You et al. (2022) investigate how China's carbon emissions trading pilot policy affects corporate green innovation. The paper emphasizes the need for introducing derivatives to stabilize carbon prices and supporting policies to enhance corporate innovation without crowding out effects. Benzanken et al (2024) explores debt-for-nature swaps as a practical financing tool for fisheries conservation. It identifies key success factors, including strong governance frameworks and stakeholder engagement. The paper offers policy recommendations for scaling up debt swap models in the fisheries sector.

Gosh et al. (2024) explore the relationship between emerging blockchain technologies (NFTs and DeFi) and carbon allowances. The study examines how these innovations intersect with carbon trading systems and impact the environmental finance landscape. This paper bridges digital financial innovations and carbon markets, showing how decentralization trends could affect carbon trading effectiveness and market stability. Alzoubi et al. (2023) investigate environmentally friendly blockchain technologies and their carbon footprints, identifying networks like Cardano and Tezos that consume less energy. It also references projects supporting greener blockchain initiatives, such as Renewable Energy Certificate Mechanisms. However, more empirical research is needed to validate these initiatives.

Concerning the natural resources cluster, literature highlights that derivatives can effectively manage the risks related to natural disasters. Avril et al. (2025) investigate the impact of natural disasters on financial stress and examine whether macroprudential policies can mitigate this effect. Using panel data across countries, the study finds that disasters significantly elevate financial stress, but strong pre-existing macroprudential frameworks can dampen these adverse effects, suggesting a crucial role for regulation in promoting financial system resilience during environmental shocks. Gill (2024) examine whether public attention to natural disasters leads to shifts in financial behavior. The results suggest that heightened media coverage of disasters influences investment choices, risk aversion, and demand for sustainable financial products. The findings highlight the importance of public sentiment in shaping financial market dynamics after environmental catastrophes. Braun (2011) presents a comprehensive analysis of catastrophe swaps, employing a contingent claims framework to price these instruments. The authors highlight the effectiveness of catastrophe swaps in transferring natural disaster risks to capital markets, emphasizing their potential to enhance financial resilience against catastrophic events. Wu and Chung (2010) delve into the intricacies of managing catastrophe risk through swaps, particularly focusing on the implications of counterparty risk. The authors propose models to mitigate such risks, demonstrating that well-structured catastrophe swaps can serve as viable tools for hedging against natural disaster-related financial exposures.

Table 3: Keyword analysis

Cluster	Keyword frequencies	Contribution of ESG-related derivatives
Green and financial innovations	finance (1100), sustainable development (917), sustainability (594), green economy (325), innovation (270), green innovation (245), sustainable development goals (218), decentralized finance (169), financial performance (137), digital finance (130), technological innovation (129), fintech (120), digitalization (106), environmental management (101), corporate social responsibility (99), environmental regulation (99), governance (93), green development (92), financial constraints (88), environmental technology (77), green technology (68), supply chain management (67), supply chain (66), environmental performance (57), manufacturing (57), circular economy (54), small and medium-sized enterprise (54), corporate governance (51), islamic finance (45), total factor productivity (43), competition (42), technology adoption (42), pollution control (41), artificial intelligence (40), digital economy (39), industrial performance (39), stakeholder (36), corporate finance (35), blockchain (34), supply chain finance (33), entrepreneurship (32), agriculture (31)	ESG-related derivatives can foster green and financial innovation by encouraging investments into innovations.
Natural resources	economic growth (301), natural resource (233), financial development (210), economic and social effects (167), economic development (157), financial inclusion (119), environmental sustainability (113), public policy (100), mineral resource (68), environmental impact (63), financial services (59), foreign direct investment (54), green growth (54), ecological footprint (47), globalization (47), ecology (46), resource rents (46), environmental quality (44), resource management (42), environmental degradation (35), sustainable growth (35), greenhouse gases (34), human capital (33), urbanization (33), resource allocation (32)	Derivatives can effectively manage the risks related to natural disasters
Renewable energy	renewable energy (204), alternative energy (131), energy efficiency (99), energy utilization (95), energy policy (88), energy (78), policy making (78), technological development (76), fossil fuel (72), energy transition (62), clean energy (54), energy market (50), energy use (50), green energy (47), energy resource (38), fiscal policy (38), spillover effect (37), uncertainty (34), policy implementation (33)	Power purchase agreements and renewable energy certificates play a key role in managing risks associated with the transition to renewable energy.
Green investments	green finance (779), investment (368), sustainable finance (351), climate change (260), green bond (216), ESG (190), financial market (170), financial system (170), risk management (112), climate finance (105), banking (66), green credit (64), green investment (45), stock market (40), greenwashing (38), credit provision (34), impact investing (32), climate risk (31)	ESG-related derivatives are effective tools for risk management and portfolio diversification.
Emission trading	environmental economics (318), carbon emission (298), carbon dioxide (260), emission control (118), environmental protection (113), environmental policy (99), carbon neutrality (41)	Carbon allowance-related derivatives can effectively manage the carbon price risk exposures, and facilitate the compliance with cap-and-trade programs

In the case of the emission trading cluster, literature demonstrates that carbon allowance-related derivatives can effectively manage the carbon price risk exposures and facilitate the compliance with cap-and-trade programs. Mhadhbi (2024) demonstrates that carbon allowances are integral parts of financial markets, alongside fossil fuels and other commodities. The study uses empirical methods to map their interdependencies and volatility transmission. The research uncovers the close linkages between carbon allowance pricing and broader commodity markets, offering insights for investors and policymakers about systemic financial risks. Li et al. (2023) examines how insurance companies incorporate green finance strategies and carbon trading mechanisms into their portfolios to address climate-related risks. It highlights the role of institutional investors, particularly insurers, in supporting sustainable finance initiatives through active participation in carbon allowance markets. Lu et al. (2024) presents a capped-call option model to price equity derivatives that incorporate the risks and opportunities created by climate policies, particularly through carbon allowances. The model suggests that carbon pricing introduces significant nonlinearities into asset returns. Through empirical tests, the study finds that companies with higher carbon exposure experience larger pricing effects. It highlights the growing necessity of including carbon risk in financial models for derivatives. This work strengthens the link between carbon markets and corporate financial risk. Li et al. (2023) models the financial interactions between insurers and borrowing producers under a carbon trading regime. It finds that carbon allowances alter the credit risk landscape, impacting both insurers' risk exposure and lending behaviors. Carbon pricing incentivizes producers to invest in greener technologies, thus lowering long-term risks for insurers. The paper highlights the systemic influence of carbon markets on broader financial intermediation structures.

Literature in the green investments cluster addresses that ESG-related derivatives are effective tools for risk management and portfolio diversification. Bhattacharjee (2024) examines the dynamic asymmetric connectedness between ESG, clean energy, and petroleum markets. The research identifies significant spillover effects among these markets, highlighting the role of ESG futures in influencing and being influenced by energy markets. You et al (2025) explore the dependencies and risk spillovers between commodity futures, stock markets, and ESG indices using a GARCHSK-Vine Copula-CoVaR methodology. The findings suggest that ESG futures can serve as effective tools for risk management and diversification in investment portfolios.

Teti et al. (2022) explores the pricing of green bonds and their relationship with credit default swaps. It provides empirical evidence that green bonds have lower yield spreads compared to conventional bonds. The findings suggest a greenium exists and is linked to lower default risk perceptions. The paper discusses implications for investors and policymakers in scaling up green finance. Cardillo et al. (2022) investigates how the credit risk of sustainable firms evolved during the COVID-19 pandemic. It finds that ESG-compliant companies demonstrated lower default swap spreads compared to conventional firms. The paper attributes this resilience to stakeholder trust and better risk management practices. Policy implications for promoting ESG in the post-pandemic recovery are discussed. Dell'Atti et al. (2022) The sovereign green bond market has been growing rapidly but its effects on national credit risk are not well understood. This paper empirically analyzes the impact of sovereign green bonds on credit default swaps and sovereign risk premiums. Results show a reduction in perceived risk, especially for emerging markets. It suggests that green bonds can be a tool for improving sovereign creditworthiness.

Literature of the renewable energy cluster introduces the role of power purchase agreements and renewable energy certificates in managing risks related to the renewable energy transition. Wang et al. (2024) explores how government environmental governance and public environmental awareness affect China's energy transition toward sustainability. The research highlights the complex interplay between local economic factors, societal engagement, and transition

progress, suggesting that customized strategies are needed. Taghizadeh-Hesary et al. (2021) address challenges in green electricity investment, like limited financing, risks, and low returns, by proposing an adjusted renewable energy power purchase agreement (PPA) model. By using local currency and channeling part of government tax revenues from green electricity spillover effects into PPAs, the model boosts returns and lowers risks. The study concludes that spillover tax revenues are a viable funding source for PPAs and recommends that developing countries allocate 50% of such revenues to support green investments through incremental PPAs.

Lee et al. (2024) evaluates the feasibility of South Korean floating offshore wind farms without government support, currently incentivized by Renewable Energy Certificates (RECs). It models a 495 MW project's financial performance under varying REC weights and explores profitability improvements when linked with green hydrogen projects. The results show that profitability (IRR) can be enhanced by lowering capital costs or raising energy prices. Rosetto (2023) examines the role of carbon markets and renewable energy certificate programs in financing sustainable waste management projects in Australia. It highlights the need for more ambitious circular economy solutions and finds that multiple support mechanisms (carbon credits, RECs, concessional finance) can together make waste-to-energy projects financially viable. Policy implications extend to Article 6.4 under the Paris Agreement and climate finance reforms. Pan et al. (2023) analyze how China's policies on fossil energy trading and renewable energy certificates (RECT) impact its low-carbon transition. While such policies reduce fossil fuel use and emissions, they initially lower GDP per capita. Renewable energy subsidies can offset short-term negative impacts and drive long-term industrial innovation and restructuring.

Figure 3 presents the overlay visualization of the co-occurrence map, highlighting the most recent research topics in green and sustainable finance. Key emerging topics include green innovation, energy transition, clean energy, and decentralized finance. In the context of green innovation, financial derivatives play a crucial role by helping manage risks and encouraging investment through hedging tools against regulatory and market uncertainties. For the energy transition, instruments such as power purchase agreements and renewable energy certificates allow investors and companies to hedge price risks associated with the shift toward renewables. Clean energy markets often face price volatility due to weather fluctuations and regulatory changes; here, financial derivatives (e.g., weather derivatives, clean energy certificate futures) offer critical risk management and price stabilization, enhancing project viability. In the realm of decentralized finance (DeFi), derivatives linked to carbon credits, energy tokens, or other sustainable assets are emerging, enabling peer-to-peer trading of environmental risks and supporting green project financing without the need for traditional intermediaries.

... a significant contribution to pr

Our research examines the potential role of ESG-related derivatives in supporting the green

In the context of the regulatory framework for sustainable finance, the treatment of derivatives remains a controversial and unresolved issue. Current approaches to sustainability reporting often incorporate derivatives into key performance indicators (KPIs) in an asymmetric manner. As policymakers revisit the regulatory framework for sustainable finance, the question of how to treat derivatives consistently within KPIs becomes increasingly urgent. In this regard, the International Swaps and Derivatives Association (ISDA) proposes applying delta-based exposure measurements and recommends proportionally including equity and bond derivatives in sustainability assessments, while excluding interest rate and foreign exchange derivatives—primarily used for hedging—from both the numerator and denominator to prevent misleading results. A balanced and consistent approach would enhance market credibility, facilitate more accurate investment decision-making, and support the integrity of sustainable finance markets as they continue to evolve.

To answer our research question RQ1, a systematic literature review was conducted, using the Scopus database as the primary source. Additionally, keyword and co-occurrence analyses were performed with the aid of VOSviewer software to map the theoretical foundations of sustainable and green finance, as well as to identify specific areas where ESG-related derivatives could have the greatest impact. Our study has some limitations, as the co-occurrence and keyword analysis reflect our subjective interpretation of the underlying literature and theoretical structures.

The analysis revealed that ESG-related derivatives contribute to the green transition in several important ways. First, they promote green and financial innovation by encouraging the development of new financial products and facilitate investments into innovation. Second, they serve as effective tools for risk management, helping to mitigate risks associated with natural resources and the volatility inherent in the renewable energy transition. Third, they play a critical role in facilitating green investments by providing investors with instruments that help align financial returns with environmental goals. Furthermore, ESG-related derivatives contribute to the efficient functioning of emissions trading systems by enabling better management of carbon price risks.

The findings of this study underscore the growing relevance of ESG-related derivatives as policymakers increasingly consider the integration of derivatives into sustainability reporting frameworks for financial market participants. As global regulatory and market environments continue to emphasize transparency, accountability, and environmental responsibility, the role of ESG-related derivative markets is poised to expand significantly, offering both challenges and opportunities for investors, institutions, and regulators alike.

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