

“From ESG principles to financial system coordination: A bibliometric analysis of sustainable finance research”

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FROM ESG PRINCIPLES TO FINANCIAL SYSTEM COORDINATION: A BIBLIOMETRIC ANALYSIS OF SUSTAINABLE FINANCE RESEARCH

Abstract

Sustainable finance has evolved from a set of environmental, social, and governance principles and specialized instruments into a field concerned with the transformation of financial institutions, markets, and public policy. This study examines the conceptual structure, temporal evolution, and cross-thematic integration of sustainable finance research, while identifying the institutional mechanisms and unresolved coordination gaps. A combined bibliometric and qualitative content analysis was conducted on 11,629 Scopus-indexed articles and reviews published between 2000 and 2025. Keyword co-occurrence mapping generated a network comprising 383 terms across four clusters, while qualitative analysis covered 30 influential and recent publications. Publication activity was highly concentrated in 2020–2025, which accounted for 84.4% of the corpus. Cross-cluster relationships represented 59.5% of the network's total weighted link strength, indicating thematic interconnectedness. The strongest integration linked green finance and the energy transition with regulation, technology, and the green economy. The qualitative synthesis identified six research streams, with banks emerging as the most prominently represented transmission channel, while coordination among monetary, prudential, fiscal, environmental, industrial and capital-market policies remained fragmented. These streams provide the basis for a preliminary five-function conceptual framework for financial system coordination encompassing information production and verification, governance, financial intermediation and investment, public-policy design and rule-setting, and digital and analytical infrastructure. The study distinguishes thematic integration within the literature from actual institutional coordination, thereby providing regulators and financial institutions with an analytical basis for designing sustainable finance policy mixes rather than relying on isolated instruments.

Keywords

sustainable finance, green finance, bibliometric analysis,
keyword co-occurrence, VOSviewer, ESG integration,
financial system coordination, green transition

JEL Classification

G21, G28, O16, Q56

INTRODUCTION

Sustainable finance has become an increasingly important component of the global response to climate change, environmental degradation, resource constraints and the social consequences of economic transformation. Financial institutions are expected not only to manage environmental, social and governance (ESG) risks within conventional decision-making processes, but also to redirect capital towards low-carbon technologies, resilient infrastructure and sustainable business models. This expansion of responsibility has moved sustainable finance beyond the boundaries of ethical investment and specialized green instruments. It now concerns the organization of the financial system itself, including the interaction of information standards, corporate governance, banking, capital markets, public regulation and technological infrastructure.

The resulting transformation is neither linear nor institutionally uniform. Environmental, social and governance disclosures may improve the information available to lenders and investors, yet inconsistent standards and rating methodologies can weaken the reliability of market signals. Green credit, climate finance and sustainability-linked instruments may facilitate investment in transition activities, but their effectiveness depends on supervisory incentives, market structure, borrower characteristics and the wider policy environment. Monetary, prudential, fiscal, industrial and environmental policies may reinforce one another, but they may also generate conflicting incentives, uneven financing conditions or unintended distributional effects. The scientific problem therefore extends beyond determining whether individual sustainable finance instruments are effective. It concerns how multiple actors, mechanisms and policy domains interact within a coordinated financial architecture.

This problem is intensified by the rapid expansion and thematic diversification of the research field. A large and heterogeneous literature now addresses ESG integration, green banking, climate-related financial risk, transition finance, green innovation, digital finance and macrofinancial policy. Although these streams share a common concern with the allocation of financial resources under sustainability constraints, they frequently employ different analytical levels, concepts and measures. Firm-level studies tend to focus on financing costs, innovation or performance; banking studies examine lending practices and institutional adoption; and policy research considers regulatory mandates, financial stability or climate governance. As a result, the relationships between these levels remain difficult to evaluate systematically.

The central scientific challenge is thus to determine whether sustainable finance is developing as a collection of adjacent but weakly connected research areas or as an increasingly integrated field capable of supporting system-level analysis. The distinction is important because financial system transformation requires more than the diffusion of individual ESG practices. It requires compatible information, coordinated institutional mandates, consistent capital-allocation incentives, and feedback mechanisms connecting financial decisions with environmental, technological, and macroeconomic outcomes. Without such coordination, the expansion of sustainable finance instruments may remain fragmented and may not translate into coherent system-wide change.

1. LITERATURE REVIEW

The development of sustainable finance reflects a gradual broadening of its normative and institutional scope. Early research linked socially responsible and ethical investment to fiduciary, regulatory and governance constraints (Richardson, 2009a, 2009b), while subsequent work incorporated climate policy, low-carbon investment, banking and monetary systems (Campiglio, 2016). This evolution has produced substantial definitional pluralism: sustainable finance may be understood as an instrument class, investment philosophy, regulatory perimeter or normative project (Migliorelli, 2021), and has been conceptualized as progressing from shareholder-value optimization towards models incorporating stakeholder, social and environmental value (Schoenmaker & Schramade, 2019). Kashi and Shah (2023) similarly emphasize coordinated regulatory, political, structural and

relational change. Sustainable finance therefore encompasses interconnected firm-, market-, and system-level processes rather than a discrete category of financial products.

A substantial strand of research examines the relationship between ESG characteristics and financial outcomes. Meta-analytic evidence generally identifies a non-negative association, although results vary across ESG dimensions, firm characteristics, and research designs (Friede et al., 2015; Gillan et al., 2021). This literature distinguishes financial-materiality motives from investor value preferences (Starks, 2023) and shows that sustainability preferences and constraints can affect expected returns, portfolio allocation, and asset pricing (Pástor et al., 2021; Pedersen et al., 2021). Empirical studies further indicate that sustainability ratings influence capital allocation, carbon exposure is priced in equity markets, and institu-

tional investors regard climate risk as financially material (Bolton & Kacperczyk, 2021; Hartzmark & Sussman, 2019; Krueger et al., 2020). However, much of this evidence derives from listed-equity markets and may not fully capture bank intermediation and prudential mechanisms. Measurement heterogeneity adds another constraint: ESG ratings remain weakly comparable across providers, while expanded disclosure does not necessarily reduce disagreement when standards retain substantial discretion (Berg et al., 2022; Christensen et al., 2021). These inconsistencies may weaken the informational signals available to firms, investors, intermediaries, and regulators.

Bank lending constitutes a critical transmission channel between firm-level ESG practices and system-level sustainability objectives. Green-banking adoption depends on regulatory support, stakeholder pressure, organizational capacity and managerial commitment (Akomea-Frimpong et al., 2022; Bukhari et al., 2022), while sustainability characteristics may affect borrowing costs, loan pricing and financing conditions (Chava, 2014; Delis et al., 2024; Degryse et al., 2023). Green-credit policies may also stimulate corporate environmental transformation, although their effects vary across firms, sectors and institutional contexts (Tan et al., 2025), and transition risks may alter the choice between bank and bond financing (Beyene et al., 2021). Banks therefore connect sustainability policy with corporate financing decisions, but these effects are neither uniform nor necessarily system-wide.

Research on green bonds examines both pricing effects and the institutional credibility underlying them. Evidence on the greenium is mixed: Zerbib (2019) identifies a small negative premium, Larcker and Watts (2020) find economically limited effects after accounting for research-design constraints, while MacAskill et al. (2021) report more frequent evidence of a greenium in primary and secondary markets. Flammer (2021) further interprets green bond issuance as a credible environmental signal. These findings suggest that pricing effects depend on certification, disclosure, and governance rather than on the green label alone. This issue connects directly with greenwashing: weak scrutiny, selective disclosure and financial constraints may create incentives for misleading environmental

claims (Delmas & Burbano, 2011; Marquis et al., 2016; Zhang, 2022a, 2022b). Sustainable financial instruments therefore require credible verification, disclosure standards, and regulatory coordination to mitigate informational asymmetries.

The limitations of instrument-level solutions have increasingly shifted attention towards sustainability as a source of systemic financial risk. Carney's (2015) 'tragedy of the horizon' provided an organizing metaphor for the temporal mismatch between climate risks and conventional financial decision-making, while Battiston et al. (2017) developed an early operational framework for assessing climate-related exposures through financial networks. Their analysis shows that direct and indirect exposures to climate-policy-relevant sectors may be material relative to investor portfolios and bank capital. Bolton et al. (2020) further characterize climate change as a 'green swan', involving interacting, non-linear, and fundamentally uncertain dynamics that cannot be adequately managed using backward-looking probabilistic techniques. Subsequent studies consolidate this systemic perspective and examine how climate-policy shocks interact with financial market conditions (Battiston et al., 2021; Roncoroni et al., 2021).

This systemic turn has been accompanied by growing research on central-bank mandates and macrofinancial instruments. Campiglio (2016) argues that carbon pricing alone is insufficient and must be complemented by banking regulation and monetary policy capable of influencing credit allocation. Campiglio et al. (2018) identify the resulting challenges for central banks and financial regulators, while Dikau and Volz (2021), examining the mandates of 135 central banks, show that many contain provisions compatible with sustainability objectives. Climate stress-testing practices nevertheless face methodological constraints because short analytical horizons, deep uncertainty, non-linearity, and endogenous interactions between climate outcomes and financial behavior are not adequately captured by conventional risk models (Battiston et al., 2021; Chenet et al., 2021). This systemic perspective makes regulatory architecture and inter-institutional coordination central to understanding how climate-related risks are governed across the financial system.

Building on this systemic perspective, attention has increasingly shifted to the regulatory architecture through which sustainability objectives are translated into classification, disclosure and supervisory practice. Since 2018, this architecture has expanded through the Sustainable Finance Disclosure Regulation, the EU Taxonomy Regulation, the Corporate Sustainability Reporting Directive, the European Sustainability Reporting Standards and the IFRS Sustainability Disclosure Standards (European Commission, 2023; European Parliament & Council of the European Union, 2019, 2020, 2022; IFRS Foundation, 2023a, 2023b). Scholarly assessment remains comparatively underdeveloped in mainstream finance, with sustainable finance research appearing more frequently in transdisciplinary outlets than in finance and economics journals (Kashi & Shah, 2023). Implementation also remains affected by definitional divergence, limited comparability, and continuing interpretive discretion (Christensen et al., 2021; Migliorelli, 2021).

A related asymmetry concerns the financial system on which the evidence is based. Asset-pricing and investor-preference studies draw predominantly on the United States, where capital allocation is relatively decentralized and mediated through disclosure, investor preferences, and market prices (Bolton & Kacperczyk, 2021; Hartzmark & Sussman, 2019; Pástor et al., 2021; Pedersen et al., 2021). By contrast, regulatory and green-banking research is more strongly associated with the European Union and other bank-oriented systems, where mandatory disclosure, taxonomy rules, prudential supervision and credit allocation play larger roles. This literature therefore reflects different coordination logics: one is primarily market-based and price-mediated, whereas the other is more institutionally and rule-driven.

Comparative financial systems research confirms that these institutional differences affect financial intermediation and capital allocation (Demirgüç-Kunt et al., 2013; Levine, 2002). De Haas and Popov (2023) find that economies with deeper equity markets reallocate investment towards less carbon-intensive sectors more rapidly

than bank-dependent economies. Coordination models derived from United States equity-market evidence therefore cannot be assumed to apply unchanged to systems in which banks intermediate most external finance. A regional dimension complicates this picture further. Vakhovych et al. (2015) conceptualize financial convergence as a regulatory and stimulatory process aimed at reducing disparities in the financial provision of social, economic, and environmental development across regions, emphasizing fiscal equalization, local-budget stability, and regional investment capacity. This indicates that capital allocation under sustainability constraints is shaped not only by the market- or bank-based character of a financial system but also by the institutional mechanisms coordinating financial resources across territories. Whether sustainable finance research integrates these market-based and bank-based coordination logics or develops them as structurally separate streams remains unresolved and provides a direct rationale for the bibliometric analysis that follows.

Bibliometric methods are increasingly used to map rapidly expanding and fragmented literatures, supported by established methodological guidance (Donthu et al., 2021; Zupic & Čater, 2015) and software environments such as bibliometrix/Biblioshiny and VOSviewer (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010). Applications to sustainable finance include bibliometric analysis of publication trends, conceptual development, and emerging research directions (Kashi & Shah, 2023). These studies establish the field's descriptive contours but do not fully explain how its principal domains are connected or which institutional mechanisms integrate them.

The limitations of existing mapping evidence partly reflect methodological choice. Co-word analysis provides transparent and interpretable representations of conceptual relationships but generally incorporates time into an aggregated network (van Eck & Waltman, 2010). Strategic-diagram and thematic-evolution procedures divide the corpus into explicit periods and are better suited to periodization (Cobo et al., 2011). Structural topic modelling permits finer tem-

poral analysis and covariate-dependent topic prevalence but is less transparent and sensitive to model specification (Roberts et al., 2019). No single method is superior across all criteria; the appropriate design depends on whether the analytical priority is thematic identification, temporal change, relational structure, or institutional interpretation.

The reviewed literature therefore reveals a progression from ESG as a firm-level attribute, through the pricing and governance of sustainable instruments, to sustainability as a macro-financial and supervisory coordination problem. However, existing studies remain divided among firm-level effects, financial instruments, bank intermediation, and macrofinancial policy. They have not jointly established how these domains evolved over time, how strongly their conceptual structures are interconnected, or which actors and mechanisms translate thematic proximity into effective financial system coordination.

This study aims to determine how sustainable finance research evolved from the analysis of individual ESG principles and instruments towards the study of financial system coordination by mapping its conceptual structure, measuring cross-cluster integration, and synthesizing the institutional mechanisms and remaining research gaps.

RQ1: What conceptual clusters and temporal shifts characterize sustainable finance research between 2000 and 2025?

RQ2: To what extent are the principal thematic clusters interconnected within the keyword co-occurrence network?

RQ3: Which actors and mechanisms underpin financial system coordination in the core literature, and which gaps continue to impede system-level analysis?

2. METHODS

The study combined bibliometric and qualitative content analysis. Bibliometric methods examined the conceptual structure, temporal evolution, and

thematic integration of sustainable finance research (Donthu et al., 2021; Zupic & Čater, 2015), while qualitative content analysis synthesized selected core publications to identify financial system coordination mechanisms and research gaps.

2.1. Data source and corpus formation

Bibliographic data were retrieved from the Scopus database on 16 June 2026. Scopus was selected because its structured metadata support publication analysis, keyword co-occurrence mapping, citation-based document selection, and science mapping.

The search strategy was designed to capture the principal concepts, institutional contexts, and financial instruments associated with sustainable finance. Its conceptual core comprised *sustainable finance*, *green finance*, *climate finance*, *carbon finance*, and *transition finance*. The institutional dimension included *sustainable banking*, *green banking*, and *responsible banking*, while the investment-related component covered *sustainable investment*, *responsible investment*, *socially responsible investment*, and *impact investment*. ESG-oriented terminology comprised *ESG finance*, *ESG investing*, *ESG investment*, and *ESG integration*. The query additionally covered major financing mechanisms and instruments, including *green credit*, *sustainable lending*, *green bonds*, *sustainability-linked bonds*, and *sustainability-linked loans*, as well as *sustainable financial system* and *financial system transformation*. The search was conducted within titles, abstracts, and keywords using the *TITLE-ABS-KEY* field. Wildcards and nested combinations were used to capture relevant lexical variants while limiting unrelated records.

The upper publication boundary was set at 2025 because 2026 represented an incomplete publication year at the time of data retrieval. Applying this boundary to the thematic search yielded 16,972 records. Restriction to articles and reviews reduced the corpus to 12,146 records, while the English-language criterion resulted in 11,803 records. Records associated with affiliations in the Russian Federation were then excluded using the Scopus *AFFILCOUNTRY* field; 145 records were removed, resulting in a pilot corpus of 11,658 publications.

Table 1. Sequential formation of the analytical corpus

Corpus formation stage	Records retained	Records excluded	Records excluded, %
Thematic search with “PUBYEAR < 2026”	16,972	–	–
Articles and reviews	12,146	4,826	28.44
English-language publications	11,803	343	2.82
Exclusion of Russian-affiliated records	11,658	145	1.23
Publication period 2000–2025	11,629	29	0.25
Final analytical corpus	11,629	–	–

Note: Exclusion percentages are calculated relative to the number of records retained at the preceding stage.

The annual distribution of the pilot corpus was subsequently examined to determine the lower temporal boundary. Only 29 records were published before 2000, and these did not constitute a sustained publication trajectory. The year 2000 was therefore selected as the lower boundary. Adding the condition PUBYEAR > 1999 reduced the corpus from 11,658 to 11,629 publications, which constituted the final analytical corpus for 2000–2025. The complete pilot and final search expressions are provided in the associated Zenodo repository (Pakhnenko, 2026). The sequential formation of the analytical corpus is summarized in Table 1.

Because the affiliation-based restriction may affect corpus composition and representativeness, the resulting dataset is treated as a specifically delimited corpus rather than as a comprehensive representation of the global sustainable finance literature. Its implications are considered in the limitations.

2.2. Keyword preprocessing and bibliometric mapping

The final bibliographic records were exported from Scopus in CSV format and processed using VOSviewer version 1.6.18 (van Eck & Waltman, 2010). Keyword co-occurrence (co-word) analysis was used to identify the conceptual structure of the field because the study focuses on thematic relationships rather than citation-based intellectual structure. The analysis incorporated all author and index keywords using the full counting method.

The minimum occurrence threshold was determined iteratively. A threshold of 25 occurrences was retained as an appropriate balance between thematic coverage and interpretability, yielding 618 initially eligible terms.

Keyword data were then standardized using a custom VOSviewer thesaurus containing 238 rules: 84 replacement or normalization rules and 154 exclusion rules. Normalization consolidated lexical variants and unambiguous abbreviations, while semantically related but non-equivalent concepts were retained separately. Exclusion rules removed generic indexing and methodological terms, biomedical indexing noise, geographical names, and other expressions that did not represent independently interpretable research themes. Following thesaurus-based preprocessing, 383 terms were retained in the final co-occurrence network. The complete thesaurus and methodological documentation are available in the associated Zenodo repository (Pakhnenko, 2026).

Clustering was performed using a resolution parameter of 1.0 and a minimum cluster size of five terms. Cluster labels were assigned after network generation based on terms with the highest total link strength (TLS) and occurrence frequency, together with the broader semantic composition of each cluster. Leading keywords were ranked primarily by TLS, with occurrence frequency reported as a complementary indicator.

Network and overlay visualizations were used to examine thematic structure and temporal positioning, respectively. In the network map, node size represents keyword occurrence frequency and links represent co-occurrence relationships; TLS measures the cumulative strength of a keyword's connections. In the overlay visualization, node color represents average publication year and therefore indicates relative temporal positioning rather than the first appearance of a topic. Annual publication counts were additionally used to contextualize these temporal patterns.

2.3. Inter-cluster integration analysis

To examine the strength and distribution of thematic integration across the clusters, an additional analysis was conducted using the VOSviewer map and network files. The map file provided the cluster membership of each keyword, while the network file contained the weighted co-occurrence links between pairs of keywords. Because the network was undirected, each keyword pair was counted once. The calculations were performed in Microsoft Excel using the exported VOSviewer map and network files.

For each pair of clusters a and b , aggregate inter-cluster link strength was calculated as:

$$C_{ab} = \sum_{i \in a} \sum_{j \in b} w_{ij}, \quad (1)$$

where w_{ij} denotes the weighted co-occurrence link between keyword i , belonging to cluster a , and keyword j , belonging to cluster b . This measure reflects the total strength of thematic connections between the two clusters.

Because the clusters differed in size, the raw inter-cluster link strength was supplemented by a size-normalized measure:

$$D_{ab} = \frac{C_{ab}}{n_a n_b}, \quad (2)$$

where n_a and n_b denote the numbers of keywords in clusters a and b , respectively. The normalized measure D_{ab} represents the average weighted link strength per potential cross-cluster keyword pair, enabling comparisons less affected by differences in cluster size.

To provide complementary pairwise comparisons, two additional derived indicators were calculated. First, the contribution of each cluster pair to the total cross-cluster link strength was estimated as:

$$P_{ab} = \frac{C_{ab}}{\sum_{p < q} C_{pq}} \cdot 100, \quad (3)$$

where the denominator represents the aggregate weighted strength of all cross-cluster links in the network. This indicator shows the relative con-

tribution of each cluster pair to the overall cross-cluster connectivity.

Second, the density of connected cross-cluster keyword pairs was calculated as:

$$L_{ab} = \frac{E_{ab}}{n_a n_b} \cdot 100, \quad (4)$$

where E_{ab} denotes the number of keyword pairs with a non-zero link between clusters a and b . This measure indicates the proportion of all potential cross-cluster keyword pairs that were actually connected.

The overall share of cross-cluster link strength in the total weighted network was calculated as:

$$S_{cross} = \frac{\sum_{a < b} C_{ab}}{\sum_{i < j} w_{ij}}, \quad (5)$$

where the numerator represents the total weighted strength of links connecting keywords from different clusters and the denominator represents the total weighted link strength of the network.

The indicator therefore measures the proportion of the network's total weighted link strength attributable to cross-cluster relationships. For reporting purposes, S_{cross} was expressed as a percentage.

These indicators were calculated as supplementary measures for the present study. They were used to characterize thematic integration within the keyword co-occurrence network and should not be interpreted as direct measures of institutional coordination among financial institutions, regulators, businesses, public authorities, or other actors.

2.4. Qualitative content analysis design

A secondary, thematically focused search was conducted by combining the original Scopus search expression with an additional block of terms related to financial system actors, institutional arrangements, and coordination mechanisms. The supplementary block included terms referring to financial systems, financial sectors, financial institutions, banks, capital markets, financial sta-

bility, and capital allocation, together with terms related to governance, regulation, coordination, integration, institutional and policy frameworks, stakeholder interaction, and public–private partnerships. The complete focused search expression is provided in the associated Zenodo repository (Pakhnenko, 2026). The focused search returned 1,395 publications.

The focused subset was used exclusively to identify publications for qualitative content analysis and did not replace or modify the original corpus used for keyword co-occurrence mapping. Publications were selected purposively using three complementary criteria. First, the 15 most cited publications across the entire 2000–2025 period were selected to represent the established intellectual base of the focused literature. Second, the five most cited publications from 2024 and the five most cited publications from 2025 were selected separately to capture recent developments. This year-specific procedure reduced the disadvantage faced by the most recent publications because of their shorter citation windows. Third, the five most productive authors in the focused subset were identified based on their number of publications, and one or two representative publications by each author were selected with regard to citation impact, recency, and thematic relevance. This procedure yielded eight distinct representative publications because some co-authored studies were selected for more than one of the five most productive authors.

The three selection components produced an initial sample of 33 unique publications. Following a thematic relevance assessment, three publications were excluded because they focused primarily on corporate environmental initiatives, broad macro-environmental outcomes, or bibliometric mapping without providing substantive evidence on institutional, regulatory, or financial system mechanisms. The final qualitative sample therefore comprised 30 publications. The purposive sample was intended to capture influential and recent studies, as well as contributions by the most productive authors, rather than to provide statistically representative coverage of the entire focused subset.

Each publication constituted the unit of analysis and was examined using a structured qualitative content analysis framework. A common coding

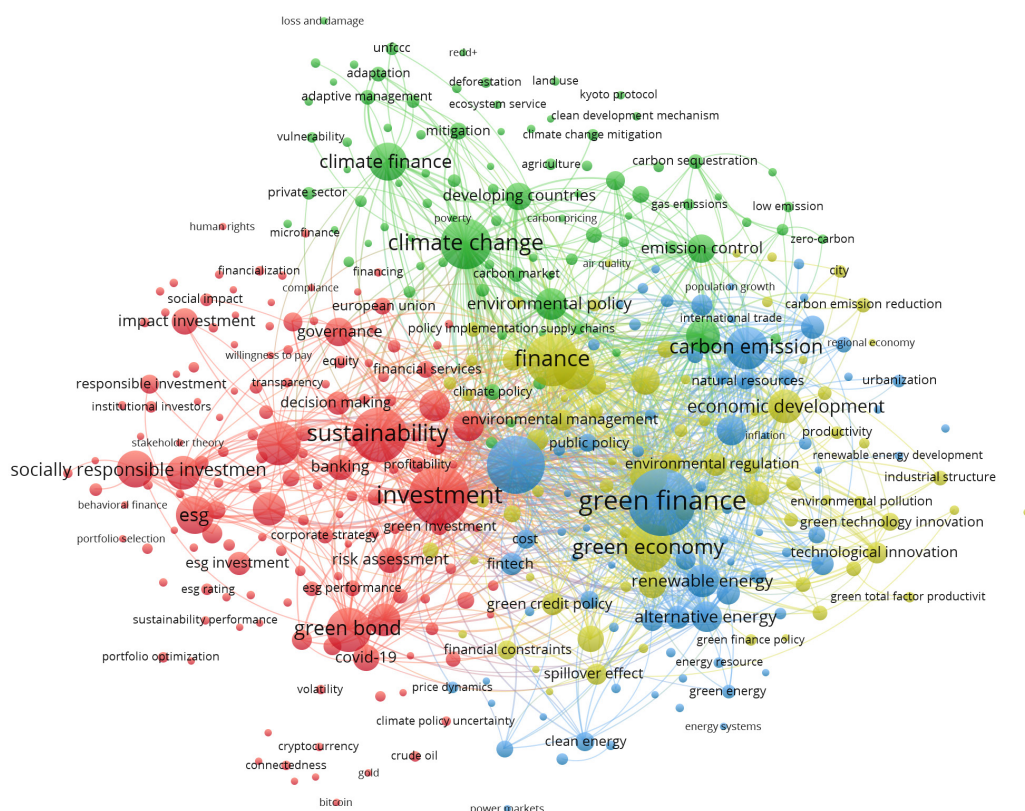
scheme covered actors and analytical levels, coordination mechanisms, regulatory and policy frameworks, financial instruments and capital allocation channels, principal findings, and research gaps. The evidence was compared across publications and synthesized into six interrelated research streams based on recurring combinations of actors, mechanisms, findings, and gaps. As the streams were not mutually exclusive, each publication was assigned to the stream representing its dominant analytical contribution, while cross-cutting relationships were retained in the interpretation.

3. RESULTS

The keyword co-occurrence network comprised 383 terms distributed across four thematic clusters (Figure 1). The map indicates that sustainable finance research is structured around four interrelated domains: ESG-oriented financial governance; climate finance and international climate-policy coordination; green finance, energy transition, and sustainable development; and the regulatory and technological dimensions of the green economy.

Cluster 1 combines investment, sustainability, financial markets, green bonds, governance, risk assessment, and ESG, representing the investment and governance foundations of sustainable finance. Although its highest-ranking terms are relatively broad, the presence of more specific concepts related to responsible investment, ESG performance, corporate governance, disclosure and risk assessment supports its interpretation as a substantively coherent cluster. Cluster 2 centers on climate finance, environmental policy, and carbon-related mechanisms; Cluster 3 links green finance with sustainable development, renewable energy, and the energy transition; and Cluster 4 combines the green economy, green credit, environmental regulation, and technological innovation. The size, thematic orientation, and leading keywords of the four clusters are summarized in Table 2.

Publication activity was highly concentrated in 2020–2025, which accounted for 9,812 of the 11,629 publications (84.4%) (Figure 2). This rapid recent



Note: Node size reflects keyword occurrence frequency, link thickness represents co-occurrence strength, and node color denotes cluster membership.

Figure 1. Network visualization of keyword co-occurrence in sustainable finance research

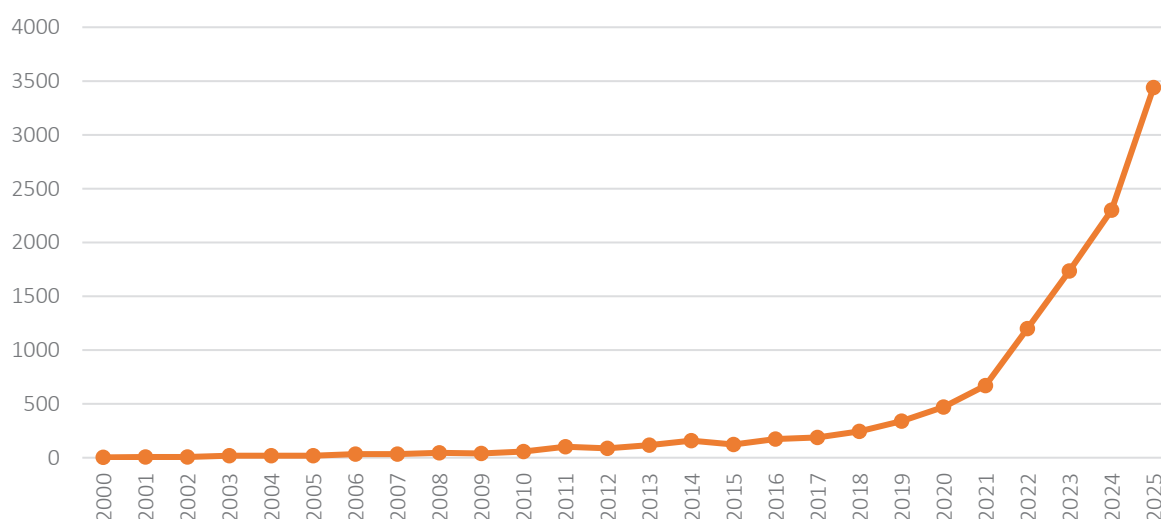
Table 2. Thematic composition of the keyword co-occurrence network

Cluster	Thematic label	Keywords n (% of network)	Leading keywords by TLS: TLS (Occurrences)	
C1	ESG, responsible investment, and financial system governance	146 (38.1%)	1. <i>investment</i>	11.225 (1.649)
			2. <i>sustainability</i>	7.926 (1.389)
			3. <i>financial market</i>	3.437 (480)
			4. <i>financial system</i>	3.377 (421)
			5. <i>green bond</i>	3.205 (919)
			6. <i>sustainable finance</i>	2.877 (851)
			7. <i>sustainable development goals</i>	2.683 (444)
			8. <i>governance</i>	2.395 (389)
			9. <i>risk assessment</i>	2.238 (288)
			10. <i>ESG</i>	1.975 (651)
C2	Climate finance and international climate-policy coordination	85 (22.2%)	1. <i>climate change</i>	7.312 (1.157)
			2. <i>carbon</i>	4.973 (534)
			3. <i>environmental policy</i>	4.168 (466)
			4. <i>emission control</i>	3.350 (370)
			5. <i>climate finance</i>	2.989 (654)
			6. <i>developing countries</i>	2.452 (348)
			7. <i>greenhouse gas</i>	1.516 (178)
			8. <i>mitigation</i>	1.077 (139)
			9. <i>carbon sequestration</i>	1.028 (108)
			10. <i>emissions trading</i>	1.005 (118)

Table 2 (cont.). Thematic composition of the keyword co-occurrence network

Cluster	Thematic label	Keywords n (% of network)	Leading keywords by TLS: TLS (Occurrences)	
C3	Green finance, energy transition, and sustainable development	78 (20.4%)	1. <i>sustainable development</i>	11.075 (1.554)
			2. <i>green finance</i>	11.035 (2.084)
			3. <i>carbon emissions</i>	6.571 (808)
			4. <i>alternative energy</i>	4.425 (438)
			5. <i>renewable energy</i>	4.224 (500)
			6. <i>economic growth</i>	3.306 (393)
			7. <i>carbon dioxide</i>	2.671 (251)
			8. <i>energy policy</i>	2.638 (263)
			9. <i>energy consumption</i>	2.272 (241)
			10. <i>energy efficiency</i>	2.018 (246)
C4	Green economy, green credit, regulation, and technological innovation	74 (19.3%)	1. <i>finance</i>	9.828 (1.284)
			2. <i>green economy</i>	9.374 (1.083)
			3. <i>environmental economics</i>	6.524 (767)
			4. <i>innovation</i>	5.206 (623)
			5. <i>economic development</i>	4.488 (511)
			6. <i>environmental protection</i>	3.552 (373)
			7. <i>green development</i>	2.696 (272)
			8. <i>environmental regulation</i>	1.997 (251)
			9. <i>environmental management</i>	1.970 (207)
			10. <i>green credit</i>	1,894 (357)

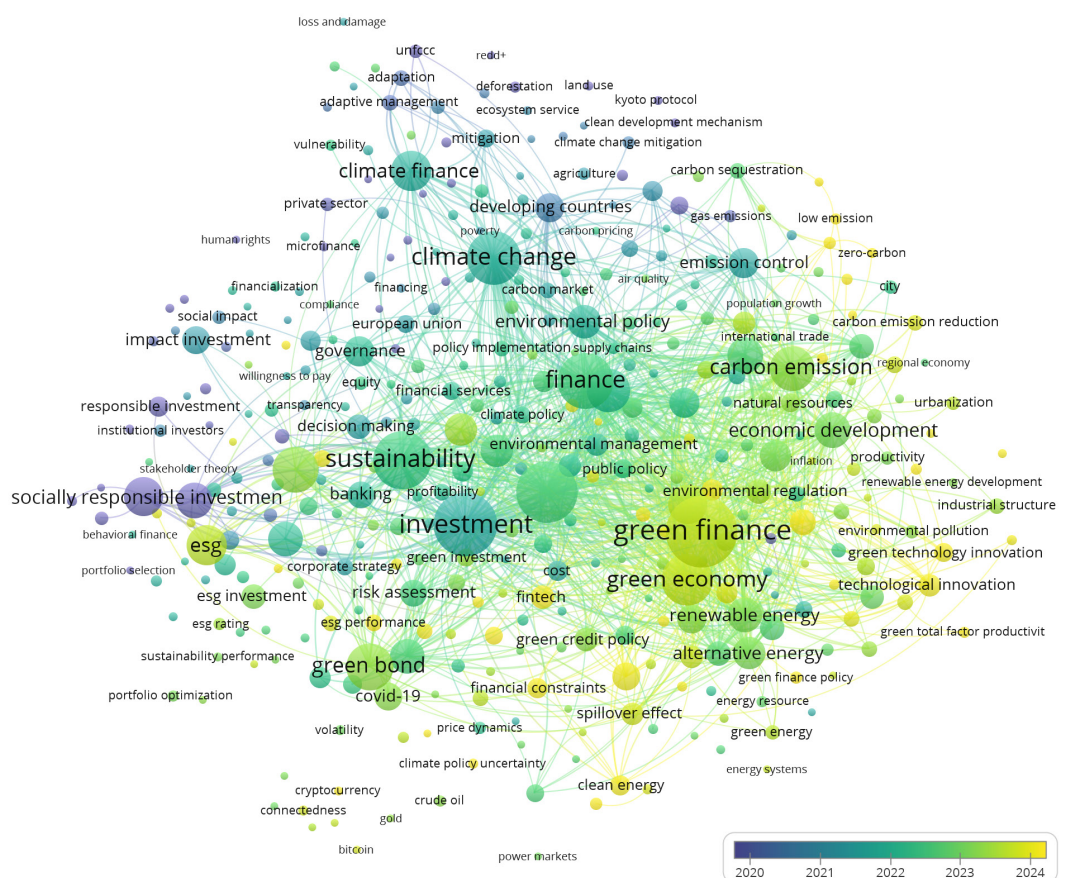
Note: TLS = total link strength; occurrence counts are shown in parentheses.

**Figure 2.** Annual distribution of Scopus-indexed publications on sustainable finance, 2000–2025

expansion also explains why most keywords have average publication years of approximately 2020 or later despite the broader 2000–2025 analytical period.

Against this publication background, Figure 3 presents the relative temporal positioning of the keyword co-occurrence network.

The overlay visualization indicates three broad and overlapping temporal layers. Earlier-positioned topics include socially responsible and responsible investment, institutional investors, portfolio selection, adaptation, mitigation, REDD+, land use and the Kyoto Protocol, reflecting the responsible-investment and established climate-policy foundations of the



Note: Node size reflects the number of keyword occurrences, link thickness represents the strength of keyword co-occurrence, and node color indicates the average publication year. Blue and purple nodes represent relatively earlier research topics, while yellow nodes indicate more recently positioned research topics.

Figure 3. Temporal overlay visualization of keyword co-occurrence in sustainable finance research

field. The intermediate layer comprises climate finance, governance, banking, investment, environmental policy, carbon markets, renewable energy and green bonds, indicating a shift towards institutional and market-based mechanisms for financing climate policy and the energy transition. More recently positioned topics include green finance, the green economy, ESG performance, green credit policy, financial constraints, green technology innovation, carbon-emission reduction and zero-carbon development, reflecting growing attention to the economic, technological and environmental effects of sustainable finance. Overall, the temporal pattern suggests a progression from responsible investment and established climate-policy mechanisms towards ESG integration and green financial instruments, and subsequently towards green finance, technological innovation and system-level sustainable transformation.

Cross-cluster links accounted for 59.5% of the network's total weighted link strength, compared with 40.5% for within-cluster links, indicating substantial thematic interconnection. As shown in Table 3, C3-C4 was the most strongly integrated pair across all four measures, linking green finance and the energy transition with environmental regulation, technological innovation, and the green economy. C1 also showed substantial connections with C3 and C4, whereas C1-C2 ranked lowest across the measures, indicating the weakest direct thematic overlap between ESG-oriented financial governance and international climate-finance research.

The qualitative content analysis of the 30 selected publications identified six interrelated research streams: ESG integration, disclosure, and ratings; institutional governance and policy coordination; green banking and capital allocation; climate and transition finance; climate risk

Table 3. Pairwise measures of inter-cluster thematic integration

Cluster pair	Aggregate inter-cluster link strength, C_{ab}	Size-normalized strength, D_{ab}	Share of total cross-cluster strength, P_{ab} , %	Cross-cluster keyword-pair density, L_{ab} , %
C3-C4	24114	4.178	24.6%	53.6%
C1-C3	18552	1.629	18.9%	31.1%
C1-C4	18092	1.675	18.4%	36.0%
C2-C4	13244	2.106	13.5%	42.2%
C2-C3	12677	1.912	12.9%	40.1%
C1-C2	11533	0.929	11.7%	27.2%

Note: Cluster pairs are ordered by aggregate inter-cluster link strength (C_{ab}) in descending order.

and macrofinancial stability; and digital finance and green innovation.

The results across the six research streams are summarized in Table A1 in the Appendix in terms of actors and analytical levels, coordination mechanisms, synthesized findings, and remaining gaps in financial system coordination. The bibliometric clusters and qualitative research streams operate at different analytical levels: the former represent keyword co-occurrence patterns across the full corpus, whereas the latter synthesize the analytical content of the 30 purposively selected publications. They should therefore be treated as complementary rather than directly corresponding classifications.

Across the six streams, recurring mechanisms provide the basis for a preliminary conceptual framework linking information production and verification, governance, financial intermediation and investment, public-policy design and rule-setting, and digital and analytical infrastructure. Banks are the most prominently represented transmission institutions in the selected literature, while interactions among banks, central banks, development finance institutions, institutional investors, rating providers, technology firms and public authorities receive less systematic attention. Similarly, monetary, prudential, fiscal, environmental, industrial and financial market policies are commonly examined separately. The literature is therefore more developed in explaining individual mechanisms and bilateral relationships than in analyzing their coordinated operation at the financial system level.

4. DISCUSSION

The findings show that sustainable finance has developed into a rapidly expanding and increasingly diversified research field, with 84.4% of publica-

tions concentrated in 2020–2025, consistent with the growth trajectory identified by Kashi and Shah (2023). The four-cluster structure indicates that the field encompasses ESG-oriented financial governance, international climate finance, green finance and the energy transition, and the regulatory and technological foundations of the green economy. The temporal analysis further suggests cumulative rather than substitutive development: ethical and responsible investment was progressively supplemented by banking, monetary-policy and macro-financial perspectives (Richardson, 2009a, 2009b; Campiglio, 2016; Dikau & Volz, 2021; D’Orazio & Popoyan, 2019; Gabor & Braun, 2025).

Cross-cluster relationships account for 59.5% of the network’s total weighted link strength, indicating substantial but uneven thematic integration rather than operational institutional coordination. The strongest relationship connects green finance and the energy transition with environmental regulation, technological innovation, and the green economy, consistent with studies linking financial and regulatory incentives to renewable-energy investment, environmental performance, and green innovation (Chang et al., 2024; He et al., 2019; Song et al., 2021; Zhang et al., 2021). By contrast, the weaker relationship between ESG-oriented financial governance and international climate finance suggests an analytical divide between firm- and market-level disclosure and investment research and macro-level climate-policy mechanisms. The transmission of corporate ESG information into national and international climate-finance frameworks therefore remains insufficiently developed.

Within the selected literature, banks are the most prominently represented transmission institutions, linking sustainability-related disclosure and supervisory requirements with financing condi-

tions and transmitting monetary, prudential and development-policy incentives to the real economy (Akomea-Frimpong et al., 2022; Bukhari et al., 2020, 2022; Fan et al., 2021; Song et al., 2021; Tan et al., 2025; Xu & Li, 2020). However, research remains more developed on bank–firm relationships than on the joint operation of commercial banks, central banks, development finance institutions, institutional investors, rating providers, and public authorities. A common framework for evaluating their combined influence on capital allocation therefore remains underdeveloped.

Based on the qualitative synthesis, these recurring mechanisms can be organized into a preliminary conceptual framework for financial system coordination comprising five interdependent functions: information production and verification; corporate and institutional governance; financial intermediation and investment; public-policy design and rule-setting; and digital and analytical infrastructure. Information providers generate sustainability-related signals, governance structures shape their interpretation, financial intermediaries translate them into financing decisions, and public policy establishes the corresponding mandates and incentives, while digital infrastructure supports information processing and transmission. The framework represents an analytical synthesis of the reviewed literature rather than an empirically validated model of financial system organization.

Within this conceptual framework, the expansion of ESG-oriented instruments cannot by itself be equated with an effective sustainability transition. The effects of ESG information and green credit depend on governance quality, rating consistency, institutional design and managerial responses (Alodat & Hao, 2025; Li et al., 2024; Tan & Zhu, 2022; Wang et al., 2024). Misaligned incentives, disclosure requirements, and monitoring arrangements may intensify financing constraints or create opportunities for greenwashing (Fan et al., 2021; Xu & Li, 2020; Zhang, 2022a). Sustainable finance effectiveness should therefore be evaluated through the consistency of information standards, supervisory rules and financial incentives with measurable environmental and financial outcomes rather than through the volume of labelled products alone.

A related coordination gap concerns the separate treatment of monetary, prudential, fiscal, environmental, industrial and financial market policies. Carbon pricing and individual financial instruments may be insufficient when other policy channels create inconsistent incentives or fail to address radical climate uncertainty (Campiglio, 2016; Chenet et al., 2021). Macroprudential instruments and central-bank mandates may support green investment and financial stability, but their calibration, interaction, and institutional legitimacy remain contested (D’Orazio & Popoyan, 2019; Dikau & Volz, 2021; Gabor & Braun, 2025). An intervention that is effective through one transmission channel may therefore be weakened or offset through another.

Within the proposed conceptual framework, digital finance and artificial intelligence constitute an enabling component of financial system coordination. They may strengthen ESG-data processing, sustainable-investment platforms and institutional capacity (Hidayat-ur-Rehman & Hossain, 2025; Lim, 2024; Vergara & Agudo, 2021), but their contribution depends on data quality, comparability, accessibility and model transparency. Digital infrastructure should consequently be treated as a governed institutional layer rather than as a neutral technical instrument.

The principal theoretical contribution of the study lies in distinguishing thematic integration within the literature from operational coordination within the financial system. A further conceptual contribution is the organization of the mechanisms identified through qualitative synthesis into a preliminary five-function framework for analyzing financial system coordination. Its methodological contribution lies in combining keyword co-occurrence mapping, pairwise inter-cluster indicators, and structured qualitative synthesis. This design connects the macro-level configuration of the research field with the institutional actors and mechanisms examined in influential and recent publications, extending bibliometric analysis beyond the descriptive identification of research themes.

Several limitations qualify the interpretation of the findings. The Scopus-based English-language corpus may underrepresent books, policy reports, non-English scholarship, and publications in-

dexed elsewhere, while keyword co-occurrence and temporal positioning depend on database indexing, author terminology, thesaurus decisions, and average publication year. The qualitative sample was purposively selected and is not statistically representative of the focused literature, while citation-based selection may favor established publications. The affiliation-based restriction may have introduced selection bias by underrepresenting particular authors, institutions, or research topics associated with Russian affiliations; the findings should therefore be interpreted as characterizing the specifically delimited corpus rather than the complete global literature on sustainable finance. Most importantly, the network indicators repre-

sent relationships among research terms and cannot be interpreted as direct measures of institutional behavior, policy effectiveness, or operational coordination.

Future research should empirically test and refine the proposed framework using integrated institutional, policy, financial and environmental data. Comparative and longitudinal studies across different financial systems and supervisory contexts, together with multi-database bibliometric and actor-centered approaches, could establish whether conceptual integration is translated into coordinated capital allocation and measurable sustainability outcomes.

CONCLUSION

This study examined how sustainable finance research has evolved from the analysis of individual ESG principles and instruments towards the study of financial system coordination. The combination of bibliometric mapping, pairwise inter-cluster analysis, and qualitative content analysis made it possible to connect the conceptual structure of the field with the institutional actors and mechanisms through which sustainability objectives are translated into financing and policy decisions.

First, the analysis of 11,629 Scopus-indexed publications identified four interrelated thematic domains: ESG-oriented financial governance; climate finance and international climate-policy coordination; green finance, energy transition and sustainable development; and the regulatory and technological foundations of the green economy. The temporal pattern indicates a progression from socially responsible investment and established climate-policy mechanisms towards ESG integration, green financial instruments, technological innovation and system-level transformation.

Second, cross-cluster relationships accounted for 59.5% of the network's total weighted link strength, demonstrating substantial but uneven thematic integration. The strongest relationship connected green finance and the energy transition with environmental regulation, technological innovation, and the green economy, whereas the weakest connected ESG-oriented financial governance with international climate-finance research. These results represent conceptual relationships within the scholarly literature and should not be interpreted as direct evidence of operational coordination among institutions.

Third, the qualitative synthesis identified six research streams and showed that banks are the most prominently represented transmission institutions, linking disclosure and regulatory signals with financing access, cost, maturity and capital allocation. However, the joint operation of commercial banks, central banks, development finance institutions, institutional investors, rating providers and public authorities remains insufficiently examined. Monetary, prudential, fiscal, environmental, industrial and financial market policies are also commonly analyzed separately, despite their potentially reinforcing or offsetting effects.

The principal theoretical contribution of the study lies in distinguishing thematic integration within the literature from operational coordination in practice and in proposing a preliminary conceptual framework for financial system coordination. Derived from the qualitative synthesis, the framework organizes the recurring mechanisms identified in the selected literature into five interdependent functions: information production and verification, corporate and institutional governance, financial intermedia-

tion and investment, public-policy design and rule-setting, and digital and analytical infrastructure. It should be interpreted as an analytical proposition requiring further empirical validation rather than as an established model of financial system organization.

The findings provide an analytical basis for evaluating sustainable finance through the consistency of information standards, supervisory rules, financial incentives and measurable sustainability outcomes rather than through the volume of labelled products alone. Given the limitations of the Scopus-based English-language corpus, keyword-dependent network construction and purposive qualitative sample, future research should empirically test the proposed framework across different institutional and financial system contexts.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Research streams, coordination mechanisms, and remaining gaps in the sustainable finance literature

Research stream	Included studies	Actors and analytical level	Coordination mechanisms	Synthesized findings	Remaining gaps in financial system coordination
ESG integration, disclosure, and ratings	Alodat and Hao (2025); Li et al. (2024); Tan and Zhu (2022); Wang et al. (2024)	Listed firms, corporate boards and sustainability committees, banks, ESG rating agencies, and investors; firm, bank–firm, and capital market levels	ESG disclosure and rating signals; internal governance oversight; ESG-informed credit pricing and investment decisions; financial constraint channel	ESG information affects firm performance, debt costs, green innovation, and stock returns; corporate governance strengthens its effects, whereas rating disagreement weakens the consistency of market signals	Lack of harmonized disclosure and rating standards; fragmented analysis of individual transmission channels; limited evidence on system-level coordination among firms, banks, rating agencies, investors, and regulators
Institutional governance and policy coordination	Cui et al. (2020); Imam and Weber (2025); Kashi et al. (2024); Richardson (2009b); Zhang (2022b)	Public authorities and regulators, financial institutions, firms, and market participants; organizational, national, cross-country, and international levels	Regulatory mandates and incentives; multi-agent cooperation; corporate governance and sustainability committees; sustainable finance networks; ESG–SDG integration and impact-reporting standards; greenwashing monitoring and financing constraint channel	Sustainable finance performance depends on aligned regulation, institutional incentives, internal governance, and stakeholder behavior. Multi-agent cooperation and sustainability-oriented governance strengthen implementation, whereas poorly aligned regulation may generate financial constraints and greenwashing	Fragmented regulation and reporting; weak harmonization of standards and impact measurement; limited public–financial–corporate coordination; insufficient evidence on policy interactions and unintended effects across institutional settings
Green banking and capital allocation	Akomea-Frimpong et al. (2022); Bukhari et al. (2020, 2022); Fan et al. (2021); Song et al. (2021); Tan et al. (2025); Weber (2017); Xu and Li (2020); Zhang et al. (2021)	Banks, firms, and public authorities; organizational, bank–firm, regional, and national levels	Green banking standards and ESG practices; stakeholder and managerial commitment; green credit regulation and differentiated lending; bank competition and financing constraints	Green banking adoption depends on regulatory, stakeholder, and managerial support. Green credit reallocates capital through differentiated financing terms, promoting green transformation, energy efficiency, and environmental improvement, with heterogeneous effects across firms, banks, and regions	Predominantly country-specific evidence; limited integration of bank-level adoption with system-wide capital allocation outcomes; insufficient cross-country, long-term, and distributional assessment of green credit effects

Table A1 (cont.). Research streams, coordination mechanisms, and remaining gaps in the sustainable finance literature

Research stream	Included studies	Actors and analytical level	Coordination mechanisms	Synthesized findings	Remaining gaps in financial system coordination
Climate and transition finance	Campiglio (2016); He et al. (2019); Lee et al. (2024); Richardson (2009a)	Public authorities and central banks, financial institutions and investors, and firms; firm, sectoral, national, and international levels	Carbon pricing and climate finance governance; monetary and macroprudential incentives; bank credit intermediation; socially responsible investment; climate-sensitive financing	Carbon pricing and market signals alone may be insufficient to redirect capital towards low-carbon activities. Banking, monetary, prudential, and investment governance mechanisms can support renewable energy investment and energy transition, but their effects depend on credit allocation, investment conditions, and climate risk	Weak integration of climate, monetary, prudential, and investment policies; limited evidence beyond the renewable energy sector; insufficient understanding of heterogeneous and potentially adverse capital allocation effects and the role of climate risk
Climate risk and macrofinancial stability	Chenet et al. (2021); Dikau and Volz (2021); D'Orazio and Popoyan (2019); Gabor and Braun (2025)	Central banks and financial regulators, governments, and financial institutions; national and macrofinancial system levels	Precautionary financial regulation; sustainability-oriented central bank mandates; climate-sensitive prudential and monetary instruments; coordination of monetary, fiscal, and credit allocation regimes	Climate risk requires a precautionary, system-level policy response. Central bank mandates and climate-sensitive prudential and monetary instruments can support financial stability and green investment, but their effects depend on coherent institutional design and policy coordination	Limited empirical validation and calibration of climate-sensitive instruments; unresolved mandate, legitimacy, and distributional issues; insufficient analysis of policy interactions, unintended effects, and regime-specific trade-offs
Digital finance and green innovation	Chang et al. (2024); Hidayat-ur-Rehman and Hossain (2025); Lim (2024); Vergara and Agudo (2021)	Financial institutions and FinTech providers, firms, investors, and public authorities; organizational, firm, financial market, and national levels	FinTech adoption and digital transformation; AI-enabled ESG analytics and decision support; green finance policy and targeted lending; digital platforms for sustainable investment	Digital technologies can strengthen sustainable finance by improving ESG information processing, investment decisions, banking performance, and green innovation. Their effects depend on green finance intermediation, organizational digital capacity, and coordinated environmental policy incentives	Fragmented digital and ESG governance; limited causal, cross-country, and long-term evidence; unresolved issues of data quality, AI transparency, user protection, and coordination among financial, technological, and regulatory actors

Note: Each publication was assigned to the research stream corresponding to its dominant analytical contribution.