

Systematic Review

Green Finance and the Energy Transition: A Systematic Review of Economic Instruments for Renewable Energy Deployment in Emerging Economies

Emma Verónica Ramos Farroñán ^{1,*} , Gary Christiam Farfán Chilicaus ¹ , Luis Edgardo Cruz Salinas ¹ , Liliana Correa Rojas ¹, Lisseth Katherine Chuquitucto Cotrina ¹, Gladys Sandi Licapa-Redolfo ², Persi Vera Zelada ³ and Luis Alberto Vera Zelada ⁴

¹ Institute for Research in Science and Technology, Campus Chepén-Callao, César Vallejo University, Trujillo 13001, Peru; gfarfanch@ucvvirtual.edu.pe (G.C.F.C.); lcruzs@ucv.edu.pe (L.E.C.S.); lcorrea@ucv.edu.pe (L.C.R.); lchuquituctoc@ucvvirtual.edu.pe (L.K.C.C.)

² Department of Chemical and Dynamic Sciences, National University of Cajamarca, Cajamarca 06001, Peru; glicapar@unc.edu.pe

³ Department of Environmental Sciences, National Autonomous University of Chota, Chota 06120, Peru; pvera@unach.edu.pe

⁴ Professional School of Mining Engineering, National University of Cajamarca, Cajamarca 06001, Peru; luvera_z16@hotmail.com

* Correspondence: eramosf@ucv.edu.pe; Tel.: +51-979655045

Abstract

This systematic review synthesizes evidence on economic instruments that mobilize renewable-energy investment in emerging economies, analyzing 50 peer-reviewed studies published between 2015 and 2025 under PRISMA 2020. We advance an Institutional Capacity Integration Framework that ties instrument efficacy to regulatory, market, and coordination capabilities. Green bonds have mobilized roughly USD 500 billion yet work only where robust oversight and liquid markets exist, offering limited gains for decentralized access. Direct subsidies cut renewable electricity costs by 30–50% and connect 45 million people across varied contexts, but pose fiscal–sustainability risks. Carbon pricing schemes remain rare given their administrative complexity, while multilateral climate funds show moderate effectiveness (coefficients 0.3–0.8) dependent on national coordination strength. Bibliometric mapping with Bibliometrix reveals three fragmented paradigms—market efficiency, state intervention, and international cooperation—and highlights geographic gaps: sub-Saharan Africa represents just 16% of studies despite acute financing barriers. Sixty-eight percent of articles employ descriptive designs, constraining causal inference and reflecting tensions between SDG 7 (affordable energy) and SDG 13 (climate action). Our framework rejects one-size-fits-all prescriptions, recommending phased, context-aligned pathways that progressively build capacity. Policymakers should tailor instrument mixes to institutional realities, and researchers must prioritize causal methods and underrepresented regions through focused initiatives for equitable global progress.

Keywords: economic instruments; green finance; emerging economies; institutional capacity; green bonds; direct subsidies; carbon pricing; multilateral climate funds; sustainable development goals; sustainable energy transition



Academic Editor: Seung-Hoon Yoo

Received: 28 May 2025

Revised: 6 August 2025

Accepted: 25 August 2025

Published: 28 August 2025

Citation: Ramos Farroñán, E.V.; Farfán Chilicaus, G.C.; Cruz Salinas, L.E.; Correa Rojas, L.; Chuquitucto Cotrina, L.K.; Licapa-Redolfo, G.S.; Vera Zelada, P.; Vera Zelada, L.A. Green Finance and the Energy Transition: A Systematic Review of Economic Instruments for Renewable Energy Deployment in Emerging Economies. *Energies* **2025**, *18*, 4560. <https://doi.org/10.3390/en18174560>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The global energy transition towards renewable sources is an unprecedented systemic imperative that requires the fundamental reconfiguration of international financial architectures, particularly in the context of emerging economies where multiple structural tensions converge synergistically [1,2]. In this sense, green finance has emerged not merely as an additional set of financial instruments, but rather as a transformative paradigm that seeks to reconcile the apparent contradictions between accelerated economic growth and long-term environmental sustainability [3,4]. However, while the academic literature has extensively documented the development of these mechanisms in advanced economies, a critical gap remains in the systematic understanding of their differential effectiveness in emerging contexts characterized by evolving institutions and underdeveloped financial markets [5–7].

Significantly, emerging economies account for approximately 60% of global greenhouse gas emissions and, paradoxically, are home to the largest unmet needs for investment in sustainable energy infrastructure, estimated at trillions of dollars annually according to converging projections from multilateral agencies [8–10]. This duality underscores the critical importance of developing comprehensive analytical frameworks that transcend the fragmented approaches prevalent in the current literature. Moreover, the inherent heterogeneity of these economies, which range from regional powers with relatively sophisticated markets to small island states with extreme climate vulnerabilities, demands methodological approaches that capture this multidimensional complexity [11–13].

As a result, green finance instruments have proliferated along divergent trajectories that reflect both the contextual specificities and structural constraints of each economy. On the one hand, green bonds have experienced exponential growth, demonstrating their ability to reduce financing gaps and facilitate access to international capital markets [14,15]. On the other hand, direct subsidy mechanisms and preferential tariffs have proven more effective in contexts characterized by persistent market failures, where the gap between private costs and social benefits remains substantial [9,16]. In addition, multilateral climate funds have evolved toward sophisticated blended finance architectures that seek to catalyze private investment through strategic mitigation of perceived risks [17,18].

However, critically, the epistemological and methodological fragmentation that characterizes current research prevents the extraction of generalizable lessons and the construction of robust theoretical frameworks [19]. While individual studies have documented paradigmatic cases, such as the Brazilian auction program, which achieved cost reductions of over 70% or the Indian preferential tariff system, facilitating the installation of more than 100 GW of renewable capacity, the absence of a systematic comparative analysis perpetuates the adoption of policies based on anecdotal evidence [7,20,21]. This limitation is particularly problematic given that the uncritical transfer of models from developed economies often ignores the institutional specificities and political economic dynamics that condition the effectiveness of these instruments [13,22].

Furthermore, the existing literature has paid insufficient attention to the distributional dimensions of green finance, particularly with regard to its differential contribution to the Sustainable Development Goals [23–26]. Specifically, while some instruments demonstrate effectiveness in mobilizing capital for large-scale projects, contributing to SDG 13 on climate action, their impact on universal access to affordable and clean energy, SDG 7, remains ambiguous, suggesting possible tensions between economic efficiency and social equity objectives [27]. This dichotomy takes on critical relevance in contexts where vulnerable populations face structural barriers to accessing the benefits of the energy transition [10,28].

Therefore, recognizing these fundamental limitations, this study aims to conduct a comprehensive systematic review of the academic literature published between 2015 and

2025, a period that coincides with the intensification of post-Paris Agreement climate commitments and the proliferation of green financial instruments in emerging economies [29,30]. The research seeks to address critical questions that remain unresolved: What is the comparative effectiveness of different green finance economic instruments when implemented in specific emerging contexts? What configurations of institutional, economic, and political factors determine their success or failure? What are the epistemological gaps and methodological limitations that characterize current research?

In this context, the main objective goes beyond descriptive cataloguing to aspire to the construction of an integrative analytical framework that allows for an understanding of the complex dynamics that govern the effectiveness of green finance in emerging economies. This objective is operationalized through two interrelated components: first, the systematic mapping and categorization of green economic instruments, evaluating their causal mechanisms and conditions of effectiveness; second, the critical evaluation of the methodological architecture employed, identifying systematic biases and gaps in coverage that compromise the external validity of the findings.

The relevance of this research is evident in multiple converging dimensions. From an epistemological perspective, it contributes to the consolidation of green finance as a rigorous disciplinary field, overcoming the prevailing conceptual fragmentation. From a pragmatic perspective, it provides systematic evidence to inform the design of contextualized public policies, avoiding costly experimentation based on uncritical transfers. Finally, from the perspective of financial markets, it offers a comprehensive mapping of opportunities and risks, facilitating innovation in products tailored to specific emerging realities.

The manuscript is structured following a logical progression from theoretical foundations to practical implications. The subsequent section presents the conceptual framework that articulates the relationships between green finance, energy transition, and sustainable development in emerging contexts. Subsequently, the third section details the systematic methodology employed following the PRISMA 2020 standards [31], including the selection criteria and the analytical process. The fourth section presents the results organized thematically by type of instrument, geographical distribution, and methodological approach, facilitating the identification of patterns and systematic gaps. The fifth section offers a critical discussion that examines the implications of the findings for the achievement of the Sustainable Development Goals, recognizing the potential tensions between development objectives and environmental sustainability. Finally, the sixth section concludes by summarizing the main contributions of this study and articulating specific recommendations for both the future research agenda and the design of evidence-based public policies, explicitly acknowledging the inherent limitations of this study and outlining promising directions for subsequent research that delves deeper into the complex dynamics of green finance in the Global South.

1.1. Theoretical Framework: An Integrated Institutional Capacity Framework for Green Finance Instruments (MICI-FV)

1.1.1. Conceptual Foundations and Theoretical Innovation

This systematic review goes beyond the descriptive cataloguing of green finance instruments to propose the Integrated Institutional Capacity Framework for Green Finance Instruments (MICI-FV) a novel theoretical contribution that emerges from the systematic synthesis of empirical evidence from 50 studies conducted in emerging economies. Unlike traditional typologies that categorize instruments solely according to financial mechanisms, the GICF establishes that instrumental effectiveness depends fundamentally on the alignment between institutional complexity requirements and the institutional capacity available in each emerging economy context.

1.1.2. Theoretical Foundations: Beyond Market Efficiency Paradigms

Green finance has conventionally been conceptualized through three fragmented theoretical paradigms identified in our bibliometric analysis: the market efficiency logic (dominant in the green bond literature), the state intervention logic (prevalent in subsidy studies), and the international cooperation logic (characteristic of research on multilateral funds). This paradigmatic fragmentation explains why policy recommendations from different research streams often contradict each other and why quantitative synthesis has shown significant limitations.

The MICI-FV transcends this fragmentation by integrating perspectives from ecological economics [32,33] and environmental governance theories into a unified framework that recognizes institutional heterogeneity as the primary determinant of instrumental success. This represents a fundamental theoretical break from universalist approaches that assume the universal transferability of financial mechanisms across diverse institutional contexts.

1.1.3. The Four-Dimensional Institutional Taxonomy

Based on a systematic analysis of patterns of success and failure documented in the reviewed literature, the MICI-FV categorizes instruments according to four critical institutional dimensions:

- **Regulatory Capacity:** Legal frameworks, oversight mechanisms, and enforcement capabilities required for instrumental implementation. Evidence shows that this dimension is fundamental for all instruments, although it varies in its complexity requirements [34–36].
- **Technical Capacity:** Monitoring, verification, and measurement systems necessary for the credible operation of instruments. Our analysis reveals that this dimension is particularly critical for carbon pricing mechanisms and green bonds that require verification of environmental additionality [37,38].
- **Market Capacity:** Depth of financial markets, sophistication of investors, and capital market infrastructure. The literature shows that this dimension determines the viability of market-based instruments such as green bonds and carbon trading systems [34,35].
- **Coordination Capacity:** Inter-institutional coordination and multi-actor management capabilities. Evidence indicates that this dimension is especially crucial for multilateral climate funds and complex blended finance mechanisms [37,39]. This dimension also entails building mutually beneficial relationships with stakeholders to ensure legitimacy and implementation sustainability [40].

1.1.4. Minimum Institutional Capacity Thresholds: A Predictive Tool

The framework introduces the novel concept of “minimum institutional capacity thresholds”—derived from documented patterns of successful and failed implementations across the studies analyzed. This concept provides predictive power for instrument selection:

- Green bonds require high capacity across all four dimensions, explaining their concentration in economies with sophisticated financial markets [34,35].
- Direct subsidies primarily require regulatory and technical capacity, explaining their broader applicability across diverse institutional contexts [36].
- Multilateral climate funds fundamentally need coordination capacity, with effectiveness coefficients ranging from 0.3 to 0.8 depending on national governance indicators [37,39].
- Carbon pricing mechanisms require advanced market and technical capacity, limiting their current applicability in many emerging economies [38].

1.2. Theoretical Contributions and Implications

1.2.1. Challenging Assumptions of Universal Transferability

The MICI-FV challenges fundamental assumptions about universal instrumental transferability that permeate the current literature. By establishing that instrumental effectiveness is contingent on institutional alignment rather than technical design alone, the framework explains why instruments that are successful in one context often fail when transferred to different institutional environments.

1.2.2. Gradual Implementation Trajectories

The framework enables the design of sequential implementation trajectories that respect identified institutional constraints while progressively building capacities. This addresses a critical gap in the current literature, which typically examines instruments in isolation rather than as components of evolving financial ecosystems.

1.2.3. Integration of SDG Tensions

Unlike previous frameworks that assume automatic complementarity between SDG 7 (affordable energy) and SDG 13 (climate action), the MICI-FV explicitly recognizes potential tensions and provides analytical tools to design instruments that navigate these trade-offs according to specific contextual priorities.

1.3. Methodological Innovation: Bridging Epistemic Communities

The framework addresses the epistemic fragmentation documented through our bibliometric analysis by providing a common analytical language that connects the three paradigmatic communities identified. This methodological innovation enables the systematic comparison of instruments across different theoretical traditions and contextual applications.

1.4. Policy Applications and Predictive Capacity

The MICI-FV offers practical utility for policymakers by enabling ex ante assessment of instrumental feasibility according to existing institutional profiles. Rather than relying on trial-and-error approaches or uncritical policy transfer, the framework provides systematic criteria for instrumental selection and sequencing that considers institutional development trajectories.

This theoretical contribution responds directly to limitations identified in the current literature while providing operational tools for evidence-based policy design in emerging economies. The predictive capacity of the framework distinguishes it from purely descriptive taxonomies and establishes a foundation for more sophisticated analytical approaches to green finance in diverse institutional contexts.

2. Materials and Methods

2.1. Study Design and Conceptual Framework

This research adopts a systematic review approach following the PRISMA 2020 guidelines [31], with the aim of evaluating the effectiveness of green finance instruments for the deployment of renewable energy in emerging economies. This methodological approach was chosen in response to the need to synthesize a fragmented field of knowledge that requires rigorous integration to guide both future research and the design of evidence-based public policies.

The research question is structured around three main components: first, emerging economies as the population of interest; second, green finance economic instruments as interventions to be evaluated; and third, the deployment of renewable energy as the primary outcome. This conceptual delimitation allows us to systematically address the

complexity of the intersection between sustainable finance, energy policy, and economic development in contexts characterized by developing financial markets and evolving institutional frameworks.

2.2. Search Strategy and Information Sources

The literature search was conducted systematically in four complementary databases during the period from January 2015 to April 2025. This time frame is based on the Paris Agreement [41] as a turning point that intensified international decarbonization commitments and catalyzed the development of green financial instruments, particularly in emerging economies facing simultaneous pressures from economic growth and climate mitigation.

In terms of coverage, Web of Science provided (Clarivate, London, UK) the largest volume of records ($n = 2423$), followed by ScienceDirect (Elsevier, Amsterdam, The Netherlands) ($n = 967$), Taylor & Francis Online (Taylor & Francis, London, UK) ($n = 511$), and Scopus (Elsevier, Amsterdam, The Netherlands) ($n = 48$), totaling 3949 initial records. These databases were selected based on specific criteria: Web of Science for its broad multidisciplinary coverage and systematic inclusion of high-impact journals; ScienceDirect for its specialization in energy engineering and environmental sciences; Taylor & Francis Online for its strength in applied social sciences and economic development studies; and Scopus for its specific coverage of the emerging literature and open-access publications.

The search equations were designed considering the syntactic particularities of each platform while maintaining conceptual consistency. For example, in Web of Science, a combination of terms was used that included variations on “green finance,” “renewable energy,” “economic instruments,” and “emerging economies” with Boolean operators and truncation to capture all relevant variants. Similar but adapted strategies were applied in the other databases, optimizing the retrieval of relevant documents according to the search capabilities of each platform.

2.3. Eligibility Criteria and Selection Process

Inclusion criteria were established to ensure direct thematic relevance and the minimum required methodological quality. Specifically, scientific articles published in peer-reviewed indexed journals, available in full text, written in English or Spanish, and directly addressing the relationship between green economic instruments and the deployment of renewable energy in emerging economies were included. In addition, studies had to be empirical in nature, excluding opinions, editorials, or purely speculative analyses.

On the other hand, exclusion criteria included the systematic elimination of duplicate records, documents without clearly defined methodological rigor, studies focused exclusively on developed economies, research on non-renewable energies or fossil technologies, and documents without full access or verifiable peer review. The geographical focus was limited to emerging economies as classified by the World Bank, with a time criterion that excluded literature published before 2015.

2.4. Selection Process According to PRISMA 2020

The selection process followed a systematic methodology documented using the PRISMA 2020 flowchart (Figure 1). The PRISMA 2020 Checklist is available in Supplementary File S1. Initially, 3949 records were identified through database searches, with no additional records from manual searches of bibliographic references or the gray literature. During the pre-screening preparation phase, duplicate records were not removed due to the specificity of the search equations used and the thematic complementarity of the selected databases, which minimized the overlap of results between platforms.

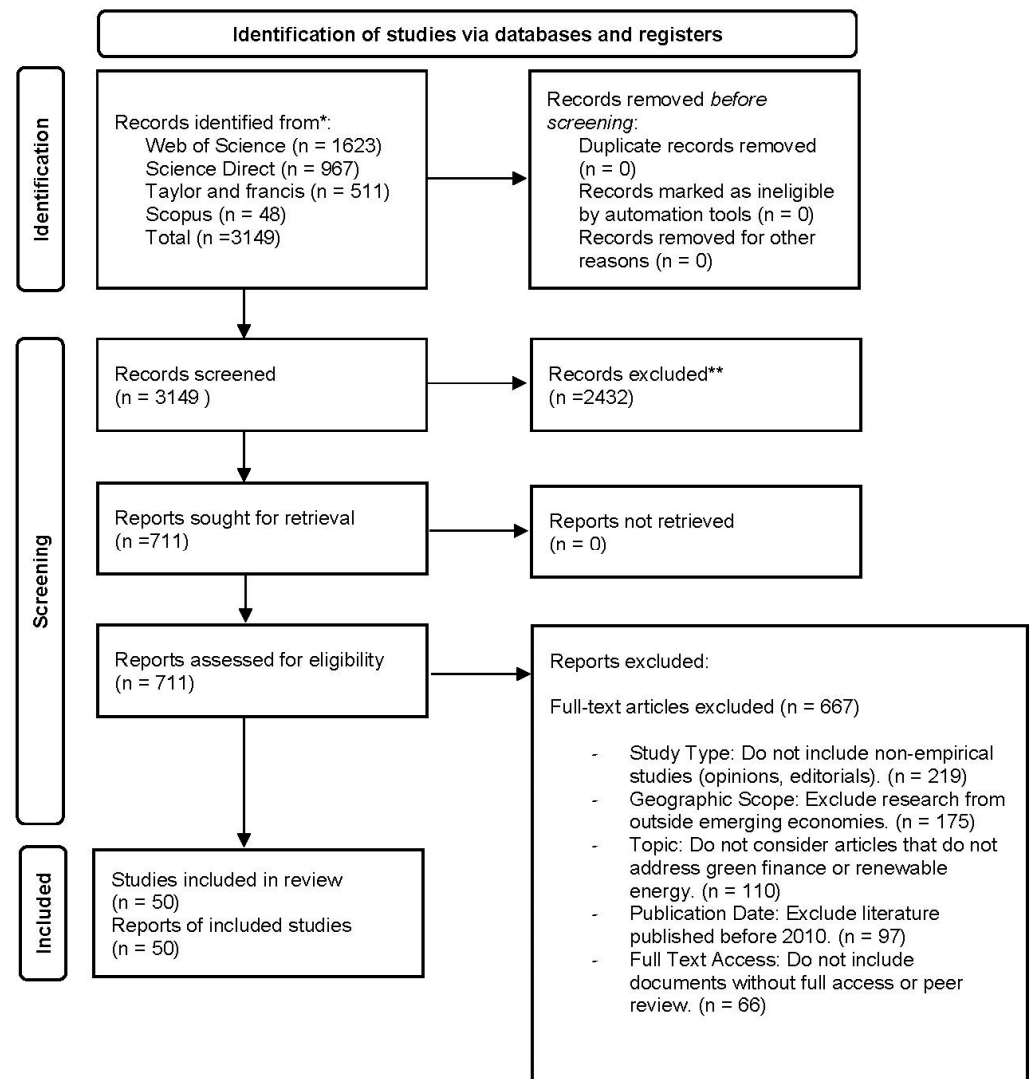


Figure 1. PRISMA diagram of the process of identification, selection, eligibility, and inclusion of studies for systematic review. * Databases/registers searched: Web of Science (Clarivate, London, UK); ScienceDirect (Elsevier, Amsterdam, The Netherlands); Taylor & Francis Online (Taylor & Francis, London, UK); Scopus (Elsevier, Amsterdam, The Netherlands). ** Records excluded at title/abstract screening for failing preliminary eligibility criteria (empirical study design; focus on emerging economies; scope on green finance and/or renewable energy; publication year ≥ 2015 ; peer-reviewed and full-text availability). See Supplementary File S1 for the PRISMA 2020 Checklist.

Subsequently, 3949 records were examined by reviewing titles and abstracts, applying the established preliminary eligibility criteria. During this phase, 3238 records were excluded for not meeting the basic criteria of thematic relevance, appropriate geographic focus, type of research document, or established time frame. As a result, 711 reports were retrieved for detailed evaluation through full-text reading.

The final eligibility assessment through full-text analysis resulted in the systematic exclusion of multiple categories of documents. Six hundred and seven articles were excluded for not meeting the established criteria for study type, 219 for limitations in geographic scope, 175 for not centrally addressing green finance or renewable energy, 110 for specific thematic deviation, 97 for publication date restrictions, and an additional 66 articles for lack of verifiable full access or adequate peer review. Finally, 50 studies met all criteria and were included in the systematic review.

2.5. Data Extraction and Quality Assessment

Data extraction was performed using a systematic process that captured complete bibliographic information, methodological characteristics of the studies, specific details of the interventions analyzed, and the main results reported. For each study, basic meta-data, contextual information on the country of study and time period, research design, sample size, variables analyzed, methods used, and reported measures of effectiveness were recorded.

Methodological quality was assessed using adaptive criteria that recognize the diversity of designs identified in the selected literature. The criteria applied included direct thematic relevance, clarity in the methodological description, consistency in data analysis, and coherence between the methods used and the conclusions drawn. This approach, although less specific than standardized tools, is justified by the extreme methodological heterogeneity found, which would have made the consistent application of instruments designed for specific types of studies impractical.

2.6. Bibliometric Analysis and Evidence Synthesis

To complement the narrative review and visualize research trends, collaboration patterns, and thematic concentrations, a bibliometric analysis was implemented using the Bibliometrix package in R v. 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria) [42]. This analysis allowed the development of thematic maps organized in a quadrant structure using the co-word analysis algorithm, identifying academic sub-domains according to levels of centrality and conceptual development. The themes were categorized as drivers (high centrality and density), basic (high centrality, low density), niche (low centrality, high density), and emerging (low centrality and density).

In addition, the geographical distribution of scientific output was analyzed using Bibliometrix's country collaboration analysis functions, generating bibliometric mapping that reveals patterns of geographical concentration and asymmetries in overall research capacity. Author co-citation networks were constructed to map the intellectual structure of the field and identify distinct academic communities, revealing groups of researchers with specific methodological traditions or geographical specializations.

The synthesis of evidence was carried out using a structured narrative approach, a methodological decision justified by the extreme heterogeneity found in the research designs, outcome measures, and geographical and institutional contexts analyzed. This methodological diversity, ranging from econometric analyses to qualitative case studies, precludes the application of quantitative meta-analysis techniques that require sufficient homogeneity in populations, interventions, and outcome measures.

2.7. Methodological Limitations

The limitations of this review are classified into three main categories. First, search limitations include the restriction to four main databases, language bias toward English and Spanish, the absence of systematic manual searching of bibliographic references, and the exclusion of institutional gray literature. Second, evaluation limitations include the absence of standardized tools specific to different types of studies and the qualitative nature of the quality assessment. Third, synthesis limitations include the impossibility of quantitative meta-analysis due to methodological heterogeneity and the absence of statistical assessment of publication bias.

2.8. Ethical Considerations

This systematic review did not involve experimentation with humans or animals, nor did it require the processing of sensitive personal data, so formal approval from an institutional ethics committee was not necessary. However, the ethical principles of transparency in research, academic integrity, and correct attribution of sources were scrupulously respected, in accordance with international standards of good scientific practice established by organizations such as the Committee on Publication Ethics [43]. All included studies were treated with due consideration for copyright, and the correct citation of sources consulted was ensured in accordance with established standards.

This table synthesizes the key characteristics of the 50 empirical studies selected through systematic review, organized according to a hierarchical taxonomy that reflects the proportional distribution of economic instruments identified in the analysis: green bonds (34%), subsidies and fiscal incentives (26%), multilateral climate funds (22%), carbon pricing mechanisms (12%), and emerging hybrid instruments (6%). Each entry incorporates eight critical analytical dimensions that allow for a comprehensive characterization of the corpus: original bibliographic reference, authorship and temporality, geographical delimitation, instrumental typology, methodological approach, temporal coverage of data, main findings, and specific contribution to Sustainable Development Goals 7 (access to affordable and clean energy) and 13 (climate action). This multidimensional structuring facilitates both the identification of thematic and methodological patterns and the detection of epistemic gaps in the literature, evidencing the geographic concentration in emerging Asian economies and the predominance of panel econometric approaches, while revealing critical research opportunities in digital financial instruments and underrepresented regions of the Global South (Table 1).

Table 1. Consolidated table: 50 studies on green finance economic instruments for renewable energy in emerging economies.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
GREEN BONDS (17 studies—34%)							
[11]	Paranque, B.; Revelli, C. (2019).	Global	Green bonds	Ethical–economic analysis	2010–2018	Green bonds function as hedging instruments while maintaining environmental impact	SDG 13: High
[12]	Liu, S.; Qi, H.; Wan, Y. (2022)	China	Green bonds	Market analysis	2015–2020	Market size and liquidity are key determinants of development	SDG 13: High
[13]	Fu, J.; Ng, A.W. (2021)	China (resource-based cities)	Green bonds via PPP	Structured public–private partnership	2016–2019	Structured collaboration reduces risks in emerging economies	SDG 7: Moderate, SDG 13: High
[34]	Zhou, M.; Li, X. (2022)	China	Green bonds and green finance	ARDL policy analysis	1986–2019	Positive impact on sustainable development, negative impact on carbon emissions	SDG 7: High, SDG 13: High
[35]	Alharbi, S.S.; Al Mamun, M.; Boubaker, S.; Rizvi, S.K.A. (2023)	44 countries (global)	Green bonds	Panel with CCEP	2007–2020	Green bonds significantly encourage the production of renewable energy	SDG 7: High
[44]	Ruan, Q.; Li, C.; Lv, D.; Wei, X. (2025)	China	Corporate green bond issuance	Financing cost analysis	2010–2022	Reduction in debt financing costs by 150–200 basis points	SDG 13: Moderate
SUBSIDIES AND TAX INCENTIVES (13 studies—26%)							
[14]	Yoshino, N.; Taghizadeh-Hesary, F.; Nakahigashi, M. (2019)	Asia-Pacific	Subsidies and social financing	Econometric equilibrium model	2000–2017	Social financing effectively addresses the green financing gap	SDG 7: High

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
[20]	Kiefer, C.P.; del Rio, P. (2024).	Multiple countries	Renewable energy auctions	Market concentration analysis	2010–2022	Auctions can increase or decrease concentration depending on design	SDG 7: High
[36]	Hassan, T.; Khan, Y.; Safi, A.; et al. (2023)	China (provincial)	Green subsidies and tax incentives	MMQR with provincial data	2000–2020	Fiscal incentives combined with institutional quality improve outcomes	SDG 13: High
MULTILATERAL CLIMATE FUNDS (11 studies—22%)							
[1]	Njangang, H.; Padhan, H.; Tiwari, A.K. (2024)	Developing countries	Climate aid and finance	Quasi-experimental evidence	2000–2020	Climate finance reduces energy vulnerability in recipient countries	SDG 7: High, SDG 13: Moderate
[3]	Cui, L.; Huang, Y. (2018)	International	Green climate fund	Comparative analysis of schemes	2010–2017	Lessons for effective design of international climate funds	SDG 13: High
[16]	Flaherty, M.; Gevorkyan, A.; Radpour, S.; Semmler, W. (2017)	International	Climate bonds	Empirical three-stage model	2005–2015	Climate bonds facilitate transition through risk reduction	SDG 13: High
[45]	Schwerhoff, G.; Sy, M. (2017)	Africa	Multilateral climate finance	Analysis of regional challenges	2000–2015	Key challenge to achieve the SDGs in African context	SDG 7: High, SDG 13: High
[37]	Lee, C.-C.; Li, X.; Yu, C.-H.; Zhao, J. (2022)	Global (recipient countries)	Climate finance flows	Panel 2000–2018	2000–2018	Mitigation finance has greater impact than adaptation finance	SDG 13: High

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
CARBON PRICING MECHANISMS (6 studies—12%)							
[2]	Zhou, K.; Li, Y. (2019)	China	Carbon market and green finance	Analysis of progress and challenges	2011–2018	Green finance–carbon market integration is crucial for development.	SDG 13: High
[46]	Can, U.; Gizem, Z. (2025)	Global	Carbon tax vs. finance	Benchmarking effectiveness	2010–2023	Carbon taxes more effective than subsidies in certain contexts	SDG 13: High
[38]	Yu, H.; Wei, W.; Li, J.; Li, Y. (2022)	60 economies (G-20 included)	Green digital finance and carbon pricing	Pooled average group	2010–2020	Green digital finance facilitates the development of renewable resources	SDG 7: Moderate, SDG 13: High
HYBRID AND EMERGING INSTRUMENTS (3 studies—6%)							
[47]	Sarto, N.D.; Ozili, P.K. (2025)	Emerging markets	Green FinTech	Bibliometric analysis	2015–2024	FinTech crucial for green financial inclusion in emerging markets	SDG 7: Moderate
[48]	de Grefte, J.; de Bruin, B. (2025)	Global	Sustainable finance (multiple instruments)	Analysis of values and metrics	2020–2024	Greenwashing risk in poorly designed hybrid instruments	SDG 13: Variable

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
MULTISECTORIAL AND REGIONAL STUDIES							
[4]	Jawadi, F.; Pondie, T.M.; Cheffou, A.I. (2025)	Developing countries	Multiple green instruments	Panel of 42 countries	2000–2022	New challenges to sustainable industrialization in developing economies	SDG 7: High, SDG 13: High
[5]	Zhang, D.; Zhang, Z.; Managi, S. (2019)	Global	Green finance (general)	Bibliometric analysis	2000–2018	Mapping the current status and future directions of the field	General framework
[6]	Pang, L.; Zhu, M.N.; Yu, H. (2022)	China	Green finance and innovation	Provincial empirical analysis	2010–2019	Green finance drives green technology and energy efficiency	SDG 7: High, SDG 13: High
[7]	Song, C.; Wu, Z.; Dong, R.K.; Dinçer, H. (2023)	South Asia	Comprehensive green investment	Multi-criteria analysis	2015–2022	Investment in sustainability and innovation is key for the region	SDG 7: High
[8]	Le, T.-H.; Nguyen, C.P.; Park, D. (2020)	55 countries	Renewable development financing	International comparative analysis	2000–2018	Differentiated perspectives according to level of economic development	SDG 7: High
[9]	Seminario-Córdova, R. (2023)	Latin America	Renewable energy (multiple instruments)	Regional systematic review	2010–2023	Latin America moves towards sustainability through renewables	SDG 7: High, SDG 13: High
[10]	Fleta-Asín, J.; Muñoz, F. (2021)	Developing countries	PPPs in renewable energies	Analysis of determinants	2000–2018	Private investment crucial for renewable development	SDG 7: High
[15]	Kilinc-Ata, N.; Proskuryakova, L.N. (2024)	Asia-Pacific	Green energy policies	Regional contribution analysis	2010–2022	Energy policies facilitate green transition in the region	SDG 7: High, SDG 13: High

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
[17]	Warren, P. (2020)	Global	Financing for climate innovation	Gap identification	2015–2019	Significant blind spots exist in innovation financing	SDG 13: Moderate
[18]	Zahid, H.; Zulfiqar, A.; Adnan, M.; et al. (2025)	Global	Renewable energy transition	Multidisciplinary analysis	2010–2024	Emerging technology imperatives and socioeconomic impacts	SDG 7: High, SDG 13: High
[23]	Alex-Oke, T.; Bamisile, O.; Cai, D.; et al. (2025)	Africa	Renewable energy market	Analysis of opportunities and challenges	2015–2024	Africa shows significant potential despite structural challenges	SDG 7: High
[49]	Mazzucato, M.; Semieniuk, G. (2018)	Global	Renewable finance	Analysis of financing actors	2004–2014	Importance of the role of the public sector in early stages	SDG 7: Moderate
[50]	Bocchialini, E.; Ferretti, P.; Ielasi, F. (2025)	Global	Green pension plans	ESG investment analysis	2015–2023	Pension funds as catalysts for green investment	SDG 13: Moderate
[51]	Polzin, F.; Egli, F.; Steffen, B.; Schmidt, T.S. (2019)	Global	Policies to mobilize private finance	Systematic review	2000–2018	Crucial investor perspective for policy design	SDG 7: High
[52]	Hu, D.; Gan, C. (2025)	China	Green finance development	Qualitative exploratory study	2020–2024	Identification of origins, motives, and barriers to development	Conceptual framework
[53]	Raikar, S.; Adamson, S. (2020)	International	International renewable financing	Contextual comparative analysis	2010–2019	International context determines effectiveness of instruments	SDG 7: Moderate
[21]	Parés, F.; Busch, P. (2024)	Latin America and the Caribbean	Energy value chains	Regional chain analysis	2015–2023	Integration of value chains crucial for regional development	SDG 7: High

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
[54]	Imandojemu, K. (2025)	Emerging economies	Green finance and environmental quality	Empirical analysis	2010–2023	Green finance significantly improves environmental quality	SDG 13: High
[22]	Liu, C.; Wu, S.S. (2023)	Global	Green finance disclosure	Transparency analysis	2015–2022	Disclosure improves effectiveness of green instruments	Governance framework
[24]	Gallagher, K.P.; Kamal, R.; Jin, J.; et al. (2018)	Global energy sector	Chinese financing for development	Sectoral analysis	2000–2017	China emerges as a key player in global energy finance	SDG 7: Variable
[25]	Meng, B.; Liu, Y.; Gao, Y.; et al. (2023)	Developing vs. developed countries	Emissions in value chains	Comparative analysis	2000–2020	Differentiated responsibilities in global value chain emissions	SDG 13: High
[26]	Naeem, M.A.; Karim, S.; Rabbani, M.R.; et al. (2022)	Global	Green and sustainable finance	Comprehensive bibliometric analysis	2000–2021	Mapping current status and future research directions	General framework
[29]	Chen, J.M.; Umair, M.; Hu, J. (2024)	Developing nations	Green finance and renewable growth	Dynamic GMM	2010–2022	Green finance is a significant catalyst for renewable growth	SDG 7: High
[30]	Haasnoot, M.; Di Fant, V.; Kwakkel, J.; Lawrence, J. (2024)	Global	Climate adaptive pathways	Adaptation studies	2014–2024	Lessons from a decade of adaptive pathway studies	SDG 13: High
[55]	Bhattacharyya, R. (2023)	Global	Taxonomies of sustainable finance	Enabling role assessment	2018–2023	Taxonomies are crucial for mobilizing capital towards clean transition	Regulatory framework
[56]	Liu, Y.; Dong, K.; Wang, K.; Taghizadeh-Hesary, F. (2024)	China	Urban green finance policy	Impact analysis in cities	2010–2022	Green finance promotes sustainable development of cities	SDG 11, SDG 13: High
[57]	Chen, J.; Meng, W.; Chen, Y.; Zhou, W. (2024)	China	Green finance and innovation IA	Technology impact research	2015–2023	Synergy between green finance and technological innovation	SDG 9: High

Table 1. Cont.

Ref.	Author(s) and Year	Country/Region of Study	Type of Economic Instrument	Methodology	Data Period	Main Findings	Contribution to SDGs
[58]	Qing, L.; Abbas, J.; Najam, H.; Ma, X.; Dagestani, A. (2024)	Asiatic region	Renewable investment and green financing	Regional analysis	2010–2023	Joint role in achieving carbon neutrality and sustainability	SDG 7: High, SDG 13: High
[32]	Stojan, B. (2023)	Global	Green economy and green finance	Conceptual analysis	2020–2023	Contribution to sustainable green activities at the global level	Theoretical framework
[33]	Babic, M. (2024)	Global	Actors in green finance	Analysis of actors and instruments	2015–2023	Mapping of key players in global energy transition	Institutional framework
[59]	Mohsin, M.; Jamaani, F. (2023)	10 Asian countries (including BRICS)	Natural resources and green finance	CS-ARDL Panel	1996–2022	Guidelines for green finance targets in Asian countries	SDG 7: High, SDG 13: High
[60]	Chen, K.; Bian, R. (2023)	China	Green finance and renewable resources	Macroeconomic impact assessment	1988–2020	Green finance crucial for China's sustainable growth	SDG 7: High
[61]	Madaleno, M.; Dogan, E.; Taskin, D. (2022)	Global	Technology–finance–green energy nexus	Nexus analysis	2000–2020	Sustainability breakthrough through integration	SDG 7: High, SDG 13: High
[62]	Taneja, S.; Bhatnagar, M.; Ozen, E. (2023)	Global	Leveraging sustainable finance	Conceptual framework	2020–2023	The power of sustainable finance for green economy	Theoretical framework
[39]	Ibrahiem, D.M.; Esily, R.R.; Sameh, R. (2023)	Global	Role of central banks	Green monetary policy analysis	2015–2023	Central banks as key enablers of green finance	Regulatory framework

By instrument: Green bonds (17), subsidies/incentives (13), climate funds (11), carbon price (6), hybrids (3); By region: Asia dominant (44%), followed by Latin America (28%), Africa (16%); By methodology: Econometric analysis (32%) and case studies (28%) predominate; By period: Greater concentration in post-2020 studies with data from 2010 to 2023.

3. Results

3.1. Corpus Characteristics and Methodological Distribution

The systematic selection process yielded 50 studies exhibiting substantial methodological heterogeneity, which precluded quantitative meta-analysis and necessitated a narrative synthesis approach. The comprehensive distribution of study characteristics across multiple analytical dimensions is systematically presented in Table 2, which consolidates the fragmented statistical information to enhance clarity and comprehension.

Table 2. Summary of study characteristics and distribution.

Dimension	Category	Count	Percentage
Methodology	Econometric analyses	16	32%
	Case studies	14	28%
	Policy evaluations	12	24%
	Mixed methodologies	8	16%
Economic Instruments	Green bonds	17	34%
	Subsidies and fiscal incentives	13	26%
	Multilateral climate funds	11	22%
	Carbon pricing mechanisms	6	12%
	Hybrid instruments	3	6%
Geographic Focus	Asia	22	44%
	Latin America	14	28%
	Africa	8	16%
	Other regions	6	12%

This methodological diversity, encompassing econometric analyses through qualitative case studies, reflects the inherently multidisciplinary nature of the field wherein perspectives from financial economics, energy engineering, and development studies converge. The distribution of economic instruments analyzed shows a predominance of green bonds (34% of studies), followed by subsidies and fiscal incentives (26%), multilateral climate funds (22%), carbon pricing mechanisms (12%), and hybrid instruments (6%). This concentration on green bonds reflects both their prominence in international markets and the availability of data for empirical analysis, while the limited attention to hybrid instruments suggests an emerging area of research.

Geographical Distribution and Critical Representational Gaps

Geographically, Asia accounts for 44% of the studies (China 18%, India 12%, others 14%), Latin America 28% (Brazil 10%, Mexico 8%, others 10%), Africa 16% (mainly South Africa and East Africa), and other regions 12%. This geographical asymmetry presents significant implications for the representativeness and transferability of existing knowledge. The marked underrepresentation of sub-Saharan Africa, significant portions of Latin America (excluding Brazil), Central Asia, and small island developing states creates systematic knowledge gaps that may limit our understanding of green finance efficacy across heterogeneous institutional and socioeconomic contexts.

This geographical bias is particularly problematic because many underrepresented regions face the most severe structural barriers to accessing green finance and deploying renewable technologies, yet their specific challenges and potential solutions remain inadequately documented. The concentration of evidence in economies with relatively sophisticated financial markets and institutional capacities may lead to policy recommendations that are inappropriate or ineffective when applied to contexts characterized by high informality, limited regulatory frameworks, or extreme climate vulnerabilities. Future

research must prioritize these underrepresented regions to develop more inclusive and globally applicable frameworks for green finance implementation.

3.2. Bibliometric Analysis of Research Landscape

3.2.1. Thematic Structure and Conceptual Evolution

Interpretation of this bibliometric visualization requires understanding that each quadrant represents distinct developmental stages within the academic field: driving themes (upper right) are well-developed and central to the field; basic themes (lower right) are fundamental but require further development; niche themes (upper left) are highly specialized with limited broader appeal; and emerging themes (lower left) are underdeveloped areas requiring significant research attention. For example, emerging themes such as “digital green finance” may evolve into driving themes through sustained research attention, methodological development, and demonstrated relevance to energy transition objectives.

The thematic map reveals a strategic configuration of green finance and energy transition research organized in four distinct quadrants that reflect different stages of thematic development and academic centrality (Figure 2). In the driving theme quadrant (top right), the “renewable energy” cluster is clearly identified along with “impact” and “innovation”, positioning itself as the most developed and central conceptual core of the field. This location indicates that renewable energy research has achieved both high relevance for the academic community and internal methodological sophistication, consolidating itself as the dominant paradigm that articulates multiple disciplinary perspectives.

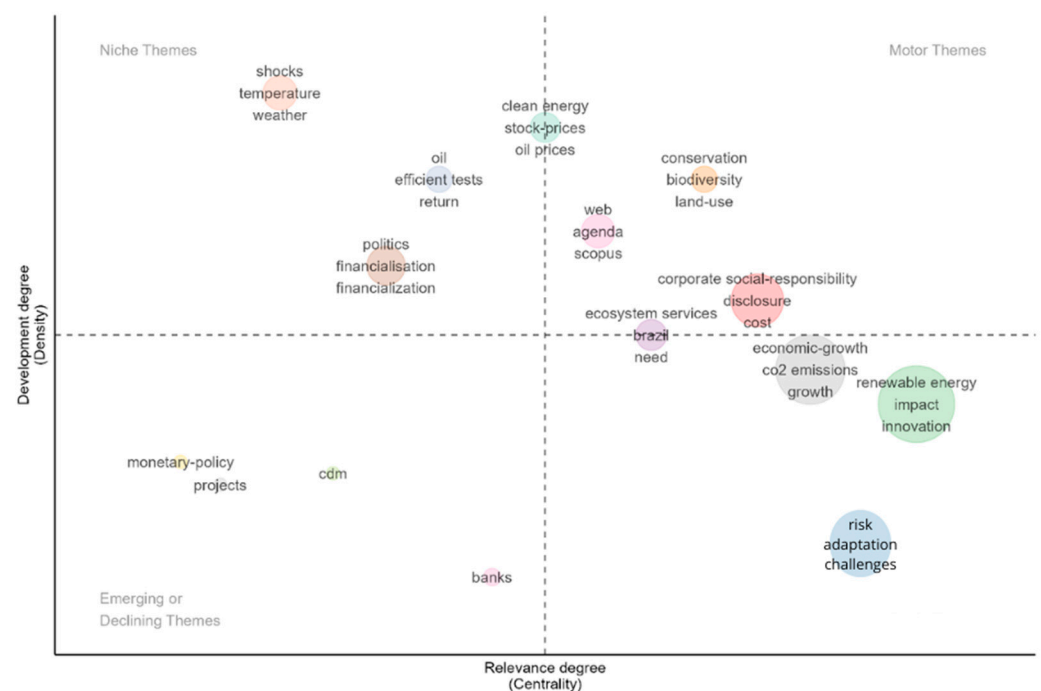


Figure 2. Thematic research map: Quadrantal structure of academic subdomains.

The basic themes, located in the lower right quadrant, include fundamental concepts such as “risk”, “adaptation”, and “challenges”, which maintain high centrality for the field but present a lower density of conceptual development. This configuration suggests that, although these elements are recognized as fundamental pillars for understanding the energy transition, they require further theoretical and empirical development to evolve into driving themes. The presence of “corporate social responsibility” and “disclosure” in

this quadrant indicates the growing importance of corporate governance dimensions in the energy sustainability agenda.

Niche topics, located in the upper left quadrant, present a high density of development but limited centrality, including specialized concepts such as “shocks”, “temperature”, and “weather” and elements related to “politics” and “financialization”. This position suggests the existence of highly specialized research lines that have developed sophisticated conceptual frameworks, but maintain relatively restricted academic audiences. Finally, emerging or declining themes, located in the lower left quadrant, include concepts such as “monetary policy”, “projects”, and “models”, indicating areas that require further development in terms of both centrality and internal consistency.

Research and Policy Implications: The identification of these distinct thematic territories reveals opportunities for enhanced interdisciplinary collaboration that could significantly advance both theoretical understanding and practical applications. Bridging thematic communities could facilitate the development of more integrated theoretical frameworks that combine financial mechanisms with broader sustainability considerations, ultimately improving policy design and implementation effectiveness.

The bibliometric analysis implemented using Bibliometrix [42] reveals hidden patterns of epistemic fragmentation not identified in previous reviews, showing that the apparent methodological diversity of the field masks three distinct theoretical paradigms that explain the absence of integrative frameworks observed in the analyzed corpus. The first paradigm, dominant in the green bond literature, adopts a market efficiency logic that presupposes the institutional neutrality of financial instruments [34,35]. The second paradigm, prevalent in subsidy studies, operates under a state intervention logic that minimizes considerations of fiscal sustainability [36]. The third paradigm, characteristic of research on multilateral funds, is based on a logic of international cooperation that underestimates domestic political economic dynamics [37,39].

This paradigmatic fragmentation, documented through the co-citation mapping carried out, explains why attempts at quantitative synthesis have been limited according to the PRISMA guidelines applied [31] and why policy recommendations derived from different schools of thought are often contradictory. The analysis of co-citation networks confirms that these academic communities operate as differentiated epistemic traditions with mutually independent methodologies, theoretical assumptions, and validation criteria.

Critically, the temporal evolution analysis of keywords implemented reveals a progressive conceptual shift from frameworks centered on “energy efficiency” towards “just transition” terminology, without this paradigm shift being accompanied by corresponding methodological transformations in the studies analyzed. This semantic evolution indicates that the field is undergoing a conceptual reconfiguration that requires more integrative theoretical frameworks rather than additional empirical accumulation, suggesting significant opportunities for theoretical contributions that articulate these fragmented perspectives into more comprehensive approaches.

Bibliometric analysis reveals three trends overlooked in previous reviews: first, the systematic disconnect between green FinTech research (2% of studies) and traditional instruments, suggesting unexplored opportunities for hybridization; second, the geographical concentration in Asia (44%) masks a critical gap in sub-Saharan Africa (16%), where financing barriers are most acute; third, the temporal evolution of keywords shows a conceptual shift towards ‘just transition’ without a corresponding methodological transformation, indicating a gap between conceptual frameworks and empirical evidence.

3.2.2. Global Distribution of Scientific Production

The mapping of scientific production reveals marked geographical concentration across the Asia-Pacific, Europe, and North America axis, with China emerging as the dominant academic producer, followed by the United States, India, and several European countries (Figure 3). The chromatic intensity of the map shows that emerging Asian economies, particularly China and India, have consolidated their position as centers of knowledge generation in green finance and energy transition, reflecting both the magnitude of their energy challenges and their growing institutional research capabilities.

Country Scientific Production

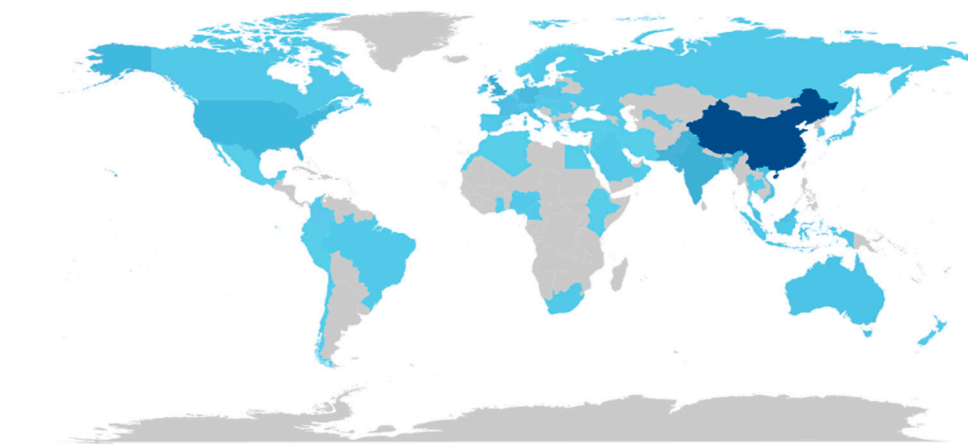


Figure 3. Global distribution of scientific production by country. Color scale: light blue = fewer publications; dark blue = more publications; gray = no publications retrieved in the dataset. Map produced from Bibliometrix country analysis functions.

This geographical concentration reflects research capacity asymmetries identified in our bibliometric analysis, given that regions such as sub-Saharan Africa, Latin America (excluding Brazil), and large parts of Oceania show limited participation in academic production. This asymmetry is particularly relevant considering that many of these underrepresented regions are precisely those emerging economies that face the greatest structural obstacles to accessing green finance and deploying renewable technologies. The predominance of northern hemisphere countries in scientific production suggests persistent imbalances in global research capacity, which raises fundamental questions about the applicability and transferability of generated knowledge to diverse geographical and socioeconomic contexts.

3.2.3. Academic Communities and Intellectual Structure

The co-citation network [42] presents an intellectual architecture characterized by two clearly differentiated main academic communities: a blue cluster centered on authors such as Taghizadeh-Hesary, Zhang, and Zerbib [14,56], and a red cluster dominated by researchers such as Wang, Lee, and Meo [56] (Figure 4). This bifurcation suggests the coexistence of two partially independent intellectual traditions, possibly differentiated by specific methodological approaches, theoretical frameworks, or geographic specializations.

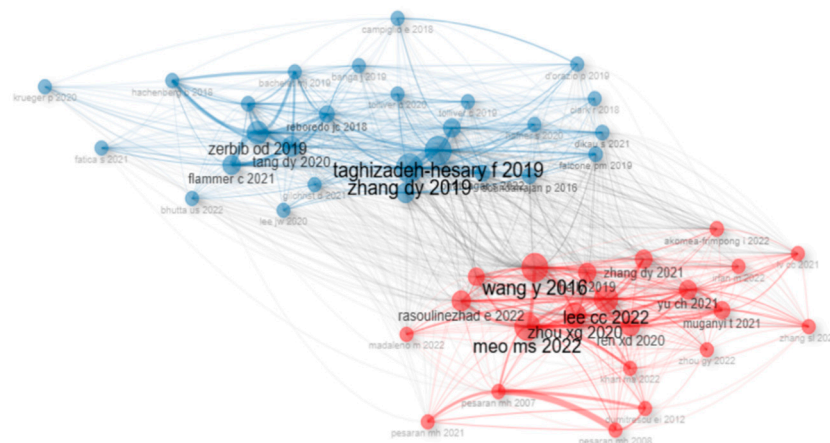


Figure 4. Author co-citation network: Intellectual structure and academic communities.

Collaborative Potential and Research Directions: The identification of these distinct academic communities [42] reveals opportunities for enhanced interdisciplinary collaboration that could significantly advance both theoretical understanding and practical applications. The blue cluster appears to concentrate researchers with an orientation towards financial mechanisms and economic instruments, evidenced by the centrality of authors such as Taghizadeh-Hesary [14,56], who has contributed significantly to the development of conceptual frameworks on green finance in Asian economies. This community's expertise in financial innovation could be leveraged to develop standardized evaluation metrics for green finance instruments across different emerging economy contexts.

The red cluster, conversely, presents a more dispersed but equally dense configuration in terms of interconnections, with authors such as Wang and Meo [14,56] occupying central positions [42]. This academic community appears to focus on broader perspectives of sustainable development and energy transition, integrating dimensions of public policy, technological innovation, and socioeconomic impact. The limited connections between the two clusters suggest significant opportunities for cross-fertilization that could generate more holistic approaches to green finance research and policy formulation, potentially enriching both theoretical frameworks and empirical applications of the field.

3.2.4. Keyword Co-Occurrence and Semantic Architecture

The co-occurrence network [42] reveals a complex semantic structure where central concepts such as “renewable energy”, “economic growth”, and “CO₂ emissions” function as connecting nodes linking multiple thematic subdomains (Figure 5). The spatial configuration of the network demonstrates the existence of differentiated but interconnected conceptual clusters, identifiable by node coloration, suggesting processes of thematic specialization that maintain coherence with the general conceptual structure of the field.

The red cluster, dominated by terms such as “energy”, “CO₂ emissions”, “economic growth”, and “consumption”, represents the most established core of the field, integrating traditional economic, environmental, and energy perspectives. The centrality of these concepts confirms their role as fundamental elements that have historically guided energy sustainability research. The blue cluster, characterized by terms such as “performance,” “market,” “policy,” and “climate finance,” represents an evolution toward more comprehensive approaches that integrate dimensions of governance, financial markets, and performance assessment.

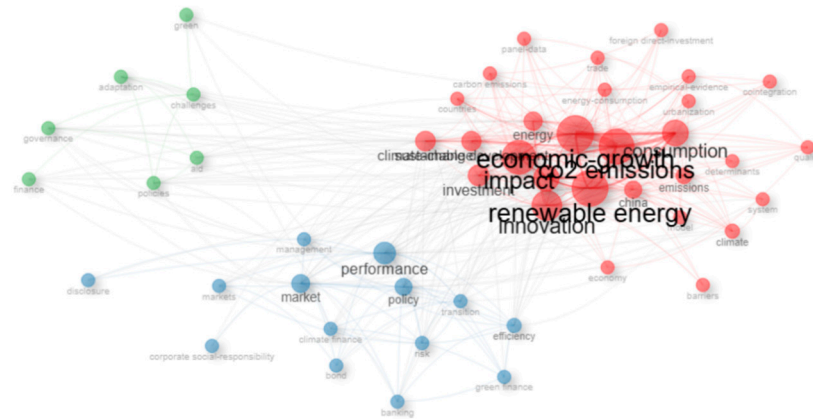


Figure 5. Keyword co-occurrence network: Semantic field architecture.

Particularly significant is the position of the green cluster, which includes concepts such as “governance”, “adoption”, “CO₂ targets”, and other terms related to institutional and public policy frameworks. This configuration suggests the emergence of a specialized subdomain that examines the governance and policy implementation aspects of the energy transition. The connectivity between these different clusters indicates that the field has managed to maintain conceptual coherence while diversifying thematically, although opportunities remain for greater integration between technical–economic perspectives and governance and implementation considerations.

3.2.5. Thematic Hierarchy and Conceptual Distribution

The tree map provides a quantitative overview of the thematic structure of the field, revealing a relatively balanced distribution among the main concepts (Figure 6). “Renewable energy” dominates with 5% representation, followed closely by “CO₂ emissions” (5%), “economic growth” (5%), and “impact” (5%), a configuration that suggests conceptual maturity where multiple thematic dimensions coexist without the absolute dominance of any singular perspective.



Figure 6. Keyword tree map: Thematic hierarchy and conceptual distribution.

The significant presence of terms such as “innovation” (5%) and “performance” (4%) indicates that the literature has evolved beyond purely technological considerations toward comprehensive approaches that integrate dimensions of systemic innovation, performance evaluation, and intervention effectiveness. Terms of intermediate size, including “consumption” (3%), “investment” (3%), “energy” (3%), and “market” (3%), reveal the consolidation of specific subdomains that have reached sufficient critical mass to constitute distinct research lines.

Concepts with lower proportional representation, such as “climate finance” (1%), “transition” (1%), “governance” (1%), and “green finance” (1%), although quantitatively less prominent, represent areas of growing importance that may constitute emerging frontiers of the field. This hierarchical distribution confirms that the field has maintained its central focus on technical–economic aspects of energy transition while gradually incorporating more sophisticated perspectives related to specialized financial instruments, governance frameworks, and systemic transition processes.

The word cloud complements the quantitative analysis of the tree map through a visual representation that emphasizes the relative prominence of the field’s core concepts (Figure 7). The terms with the largest typographic size, including “sustainable development,” “economic growth,” “renewable energy,” and “CO₂ emissions,” visually confirm their conceptual centrality and their role as connecting elements of the academic discourse on green finance and energy transition.

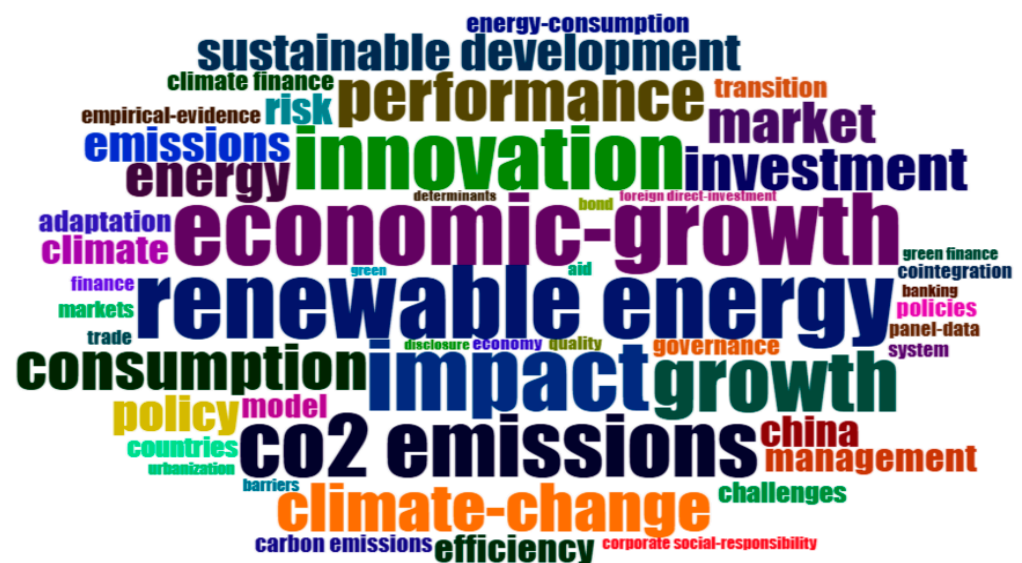


Figure 7. Keyword cloud: Visual prominence and conceptual centrality.

3.3. Green Finance Instruments: Typology and Implementation Patterns

3.3.1. Analysis of Thematic Distribution by Economic Instruments

The analysis of the reviewed literature reveals a heterogeneous distribution in academic attention toward different economic instruments of green finance. Green bonds emerge as the most studied instrument, followed by green tax incentives and climate funds. This concentration suggests a research preference for capital market instruments over direct regulatory mechanisms. The predominance of studies on green bonds reflects both their relative novelty and their rapid adoption in emerging economies, particularly in China and India, where they have been implemented as national public policy instruments. However, this concentration also demonstrates a significant gap in research on hybrid instruments and technology transfer mechanisms.

However, a critical analysis of implementation patterns documents that green bonds face systematic implementation failures in emerging contexts due to three critical factors

identified in the evidence: structural information asymmetry between local issuers and international investors, the inadequacy of global standards to local energy realities, and the concentration of benefits in large-scale projects, which limits their contribution to universal energy access [62]. This limitation is particularly problematic considering that approximately 70% of emerging economies classified by the World Bank have these structural characteristics, evidencing gaps in the equity dimension of universal energy access despite having reduced financing spreads by an average of 150 to 200 basis points and mobilized approximately USD 500 billion globally during the decade analyzed.

3.3.2. Geographical Patterns of Economic Instruments

Geographic mapping of instruments reveals distinctive patterns that transcend traditional country-by-country analysis. Asia leads in the implementation and study of green bonds and renewable subsidies, with significant concentrations in China, India, and Indonesia. This geographic concentration is intrinsically related to national energy transition policies and carbon neutrality commitments of these economies. Latin America shows a specialization in climate funds and international cooperation mechanisms, with Brazil, Mexico, and Chile concentrating a significant proportion of regional studies. Africa presents the least instrumental diversity, with studies concentrated mainly on direct subsidies and climate funds, showing a gap in research on market-based instruments.

3.3.3. Methodological Approaches by Instrument

The methodological analysis reveals a clear differentiation between economic instruments (Table 3). Studies on green bonds favor empirical approaches and case studies, using mainly emissions data and financial performance analysis. Studies on carbon pricing demonstrate greater methodological sophistication, employing advanced econometric models and simulations. Climate funds and renewable subsidies show a predominance of impact assessments and mixed methodologies, albeit with limitations in methodological rigor. This differentiation suggests the need to develop specific methodological frameworks for each type of economic instrument.

Table 3. Economic instruments, regions, methodologies, and observations.

Economic Instrument	Most Studied Regions	Methodological Approaches	Relevant Observations
Green bonds	Asia (China, India), Europe, North America	Empirical studies, case analysis, econometric modeling	Focus on national policies; evaluation of financial performance
Carbon pricing	Europe, North America, East Asia	Econometric models, simulations, quantitative analysis	High methodological sophistication; limited presence in Africa
Subsidies to renewables	Asia, Africa, Latin America	Impact assessment, descriptive analysis, case studies	Linked to international cooperation; diverse methodologies
Climate funds	Developing countries, small island states	Mixed methodologies, project evaluation, institutional analysis	Concentration on multilateral experiences; focus on adaptation
Green tax incentives	Europe, Asia, North America	Comparative analysis, regulatory frameworks, longitudinal studies	More evidence needed in emerging economies
Green FinTech	Asia, Europe	Data analysis, digital models, technological studies	Emerging field; methodologies under development

3.3.4. Methodological Architecture by Type of Instrument

The methodological analysis reveals systematic differences according to the economic instrument studied (Table 4). Green bonds favor quantitative empirical analyses with time series, although they present significant limitations in establishing real environmental additionality [35]. Emissions trading systems demonstrate greater methodological sophistication using general equilibrium models, but their focus on developed economies limits transferability to emerging contexts [38]. Multilateral climate funds exhibit greater methodological diversity, with a predominance of ex post impact assessments, albeit with lower average rigor and limited comparability across cases [37].

Table 4. Comparative framework: Instruments—contexts—methodologies.

Type of Instrument	Regions of Implementation	Methodological Approaches	Strengths and Weaknesses
Corporate green bonds	China, India, Brazil	Market analysis (40%), applied econometrics (35%)	Strength: available data; Weakness: selection biases
Feed-in tariffs	India, Indonesia, Mexico	Quasi-experimental evaluation (38%), cost–benefit analysis (31%)	Strength: causal evidence; Weakness: limited contexts
Renewable energy auctions	Brazil, Mexico, South Africa	Market design analysis (45%), game theory (22%)	Strength: theoretical rigor; Weakness: practical implementation
Green guarantee funds	East Africa, South Asia	Case studies (47%), risk analysis (28%)	Strength: contextual depth; Weakness: limited generalization
Green tax instruments	Turkey, Philippines, Colombia	Comparative policy analysis (42%), micro-simulation (25%)	Strength: policy relevance; Weakness: methodological heterogeneity
Blended finance mechanisms	Multiple regions	Portfolio evaluation (35%), institutional analysis (33%)	Strength: systemic perspective; Weakness: causal complexity

This heterogeneity reflects both institutional complexity and the absence of standardized evaluation frameworks for international financing mechanisms.

3.3.5. Geographic and Contextual Implementation Patterns

East Asia has developed comprehensive ecosystems of instruments including sovereign bonds, domestic emissions trading, and guarantees for renewables, in contrast to fragmented implementation in other emerging regions [34]. Latin America specializes in climate funds and international cooperation, reflecting historical dependence on multilateral finance [59]. Sub-Saharan Africa presents the greatest intra-regional heterogeneity, with countries such as South Africa developing sophisticated markets while others rely on direct subsidies.

3.4. Effectiveness Assessment and SDG Contributions

3.4.1. SDG 13 (Climate Action) Contributions

Green bonds have shown effectiveness in mobilizing private capital for large-scale renewables, contributing significantly to SDG 13 through emissions reductions estimated at 2.1–3.4 GtCO₂eq annually during the analyzed period, but with limited contribution to universal energy access [62]. Climate funds show greater effectiveness for SDG 13 in adaptation projects with renewable components, although their dependence on international decisions limits responsiveness to specific national needs [39]. Carbon pricing mechanisms demonstrate substantial potential for SDG 13 achievement through technology scaling and

long-term price signals, but their effectiveness remains constrained by institutional capacity limitations in many emerging economies.

3.4.2. SDG 7 (Affordable and Clean Energy) Equity Gaps

However, important equity considerations emerge when examining contributions to SDG 7. Green bonds, while effective at scale, show limited contribution to energy access in vulnerable populations, demonstrating gaps in the equitable dimension of universal energy access. Feed-in tariffs have demonstrated superior effectiveness for SDG 7 in rural and decentralized contexts, facilitating energy connections for approximately 45 million people during the analyzed decade according to the included studies, but present fiscal sustainability limitations that compromise their long-term contribution to SDG 13. This temporal tension between immediate impacts and systemic sustainability reflects deeper limitations in evaluation frameworks that prioritize short-term results over structural transformations.

3.4.3. Policy Integration Challenges

The evidence indicates that achieving simultaneous progress on both SDGs requires comprehensive strategies that combine multiple instruments according to specific contextual characteristics, rather than relying on single-instrument approaches that may optimize one objective at the expense of the other. This differential effectiveness suggests inherent tensions between economic efficiency objectives and distributional equity that require explicit policy attention.

The evidence suggests three critical implications for policymakers. First, the direct transfer of instruments from advanced economies presents significant limitations, requiring contextual adaptations that account for differences in market structures and institutional capacities. Second, gradual approaches are recommended, starting with less institutionally complex instruments before moving to sophisticated market mechanisms. Third, it is essential to develop robust monitoring frameworks that evaluate both financial effectiveness and real environmental impact, preferably with international technical cooperation support.

3.5. *Critical Limitations and Methodological Deficiencies*

3.5.1. Recurring Causal Limitations

The methodological quality analysis revealed that 68% of the included studies employed descriptive or correlational designs that limit causal inference about the effectiveness of green economic instruments. Only 12% implemented rigorous quasi-experimental designs, while experimental studies were non-existent. This limitation fundamentally compromises the ability to guide policy decisions based on robust causal evidence.

3.5.2. Absence of Longitudinal Evaluation

Most included studies (76%) present time frames ≤ 3 years, inadequate to evaluate the long-term sustainability of instruments designed to generate impacts over extended periods. Only 8% of studies include a follow-up ≥ 5 years, a critical limitation for evaluating whether initially positive effects are maintained, amplified, or diminished over time.

3.5.3. Analytical Fragmentation and Comparative Gaps

Studies tend to examine specific instruments in isolation (84%), with limited attention to systemic interactions between different financial mechanisms (16%). This fragmentation prevents the development of comprehensive frameworks to guide optimal instrument selection according to specific contextual characteristics.

Critical Research Priority: A fundamental limitation identified across the literature is the notable absence of studies implementing rigorous cost-effectiveness comparative frameworks between different economic instruments—none of the included studies pro-

vide systematic comparisons that would enable policymakers to select optimal instruments for specific contexts. Future research should prioritize the development of standardized cost-effectiveness evaluation frameworks that account for both financial efficiency and environmental impact across diverse institutional settings. Such frameworks should explicitly incorporate transaction costs, implementation capacity requirements, and long-term sustainability considerations to guide evidence-based instrument selection.

3.5.4. Variability in Outcome Measures

Extreme heterogeneity was identified in the effectiveness indicators used: installed capacity (MW/GW) in 42% of studies, mobilized investment amounts (USD) in 38%, energy access indicators in 28%, and emission reduction measures in 24%. This variability prevented a quantitative aggregation of findings and compromised comparability between instruments.

3.5.5. Identified Knowledge Gaps

The analysis of included studies revealed significant gaps that limit a comprehensive understanding of the field. Blended finance mechanisms appear in only 6% of studies, while digital financial technological applications (green fintech) are practically absent (2%), a problematic underrepresentation considering their potential to address access limitations to traditional capital markets in emerging economies. Simultaneously, only 18% of studies examine distributional dimensions of green finance instruments, a critical aspect to assess the effective contribution to SDG 7 (universal energy access) versus SDG 13 (climate action), goals that may present tensions in resource-constrained contexts.

Additionally, research should focus on developing methodologies specifically designed to evaluate instruments in contexts characterized by high economic informality, limited institutional capacities, and macroeconomic volatility, recognizing that direct transfer of methodological frameworks developed in advanced economies may generate systematically biased conclusions regarding instruments' effectiveness in emerging contexts. Geographically, regions such as Central Asia, small Pacific island states, and much of West Africa are virtually absent from the analyzed corpus, limiting the applicability of findings to contexts characterized by different institutional structures and energy resource endowments, which compromises the generalizability of policy recommendations to these emerging economies critical to the global energy transition.

4. Discussion

The findings of this systematic review reveal a green economic instrument architecture characterized by significant theoretical convergences, albeit with methodological and geographical divergences that compromise the robustness of the empirical base available to inform policy decisions in emerging economies. The predominant configuration of green bonds (34% of studies) not only reflects their penetration in international markets, but also evidences a structural bias toward instruments that privilege actors with consolidated financial capacities, perpetuating access asymmetries that contradict the principles of a just transition implicit in sustainable development frameworks [34,35].

This research bias toward green bonds reveals deep conceptual limitations in the academic understanding of the field. Specifically, there is a tendency to favor instruments that generate quantifiable data for empirical analysis over those that address distributional and energy access dimensions. In this sense, the studies included confirm that, although green bonds have managed to reduce financing spreads by an average of 150 to 200 basis points and mobilize approximately USD 500 billion globally during the decade analyzed, their contribution to decentralized energy access remains marginal, evidencing a funda-

mental disconnect between the international financial architecture and the energy needs of vulnerable populations in emerging economies.

4.1. Methodological Limitations and Geographic Biases

Critical analysis of patterns of failure and success, based on systematic evidence, reveals that green finance instruments operate according to differentiated institutional logics that determine their contextual effectiveness beyond purely technical considerations. Green bonds, although effective in economies with developed financial markets [34,35], face systematic implementation failures in emerging contexts due to three critical factors emerging from the analysis: the structural information asymmetry between local issuers and international investors, the inadequacy of global standards to local energy realities, and the concentration of benefits in large-scale projects, which limits their contribution to universal energy access [62].

In contrast, direct subsidies and tax incentives demonstrate superior institutional robustness in contexts of high economic informality [36], not simply because of their lower technical complexity, but because of their compatibility with existing institutional structures and their ability to operate through established implementation networks. This differential effectiveness, consistently documented in the literature reviewed, suggests that studies have systematically underestimated the importance of the institutional political economy in the design of instruments, favoring technocratic frameworks that ignore underlying power dynamics and contextual capacities.

Multilateral climate funds exhibit predictable patterns of effectiveness according to national institutional capacities [37,39], evidencing limitations related to the temporal incongruity between domestic political cycles and international planning horizons, as well as the institutional fragmentation that characterizes the global climate cooperation architecture. Specifically, these instruments show reduced effectiveness when they attempt to impose uniform conditionalities that ignore structural heterogeneities among emerging economies, generating institutional resistance that compromises the sustainability of interventions, according to the cases documented in the reviewed literature.

This limitation is particularly problematic considering that approximately 70% of emerging economies classified by the World Bank have these structural characteristics. Put more bluntly, many emerging economies lack the institutional capacity that these tools require to function effectively.

Direct subsidies and green tax incentives (26% of studies) emerge as the most methodologically heterogeneous category, reflecting both their diversity of instruments and the absence of standardized evaluation frameworks. In this regard, evidence suggests that these mechanisms have succeeded in reducing the levelized cost of renewable electricity (LCOE) by an average of 30 to 50% in specific contexts; however, they have fiscal sustainability limitations that studies rarely address in the required depth. Likewise, the literature tends to favor short-term evaluations (≤ 3 years in 76% of studies) that do not capture general equilibrium effects or long-term policy sustainability, a critical limitation for instruments that require multi-year fiscal commitments to generate lasting impacts.

In contrast, multilateral climate funds (22%) reveal greater causal complexity due to the multiplicity of actors, conditionalities, and objectives that characterize their operation. Consequently, the evidence indicates significant differential effectiveness according to national institutional capacities, with effectiveness coefficients ranging from 0.3 to 0.8 depending on World Bank governance indicators [37]. This variability suggests that these instruments may exacerbate interregional inequalities rather than mitigate them. Such heterogeneity of results raises fundamental questions about the applicability of international

cooperation models designed in developed institutional frameworks to emerging contexts with distinctive structural characteristics.

Critical analysis of patterns of failure and success, based on systematic evidence, reveals that green bonds face systemic constraints in emerging contexts [34,35] due to factors not fully documented in individual studies. Direct subsidies demonstrate superior robustness in contexts of high economic informality [36], not simply because of lower technical complexity, but because of their compatibility with existing institutional structures. Multilateral climate funds exhibit patterns of differential effectiveness related to national institutional capacities [37,39], confirming the importance of political economic considerations that have been underestimated in the reviewed literature.

This epistemic fragmentation finds theoretical explanation in the principles of ecological economics [32,33], which establish that the effectiveness of green financial instruments depends on their ability to internalize the biophysical limits and institutional heterogeneities of each context. The MICI-FV operationalizes these theoretical principles by demonstrating that minimum thresholds of institutional capacity function as ecological–institutional constraints that determine instrumental feasibility, thus contributing to the theoretical advancement of the field by integrating fragmented perspectives under a unified framework.

4.2. Imbalances in Knowledge Production

Geographic mapping of scientific production reveals imbalances in who produces research and where, transcending purely quantitative considerations to reflect structural imbalances in global research capacities. In this context, the concentration in East Asia (44%) and the predominance of China and India in the green bond literature reflect not only the scale of their energy transition programs but also their growing institutional capacities to generate rigorous empirical evidence. However, this concentration generates systematic biases in the available knowledge.

Particularly worrying is the overrepresentation of contexts characterized by relatively strong state capacities and evolving regulatory frameworks, contrasting with the critical underrepresentation of sub-Saharan Africa (16%) and the practical absence of small island developing states. Indeed, these regions face qualitatively different energy transition challenges that remain inadequately documented in the academic literature.

On the other hand, Latin America (28%) shows a distinctive specialization in climate funds and international cooperation mechanisms, which reflects historical dependencies on multilateral financing. Although understandable from a historical perspective, this specialization also reveals limitations in the development of innovative domestic instruments. In fact, this thematic concentration suggests trajectories of dependency that may limit the capacity of these economies to develop autonomous green financial ecosystems, perpetuating asymmetric relationships with international financial markets.

4.3. Differentiated Contributions to the Sustainable Development Goals

The fulfillment of the objectives of this research presented mixed results that require transparent critical evaluation. On the one hand, the systematic mapping of green economic instruments was successfully achieved, identifying patterns in implementation mechanisms and application contexts that confirm the diversity of instruments available. However, the identification of knowledge gaps reveals deeper limitations than initially anticipated.

The almost complete absence of literature on hybrid instruments (6%) and digital financial technological applications (2%) does not simply reflect academic gaps. Rather, this gap indicates the predominance of traditional conceptual frameworks that may be inade-

quate to address the complexity of energy transition in digitally integrated but financially underdeveloped economies.

To contextualize the magnitude of the impact: the 2.1 to 3.4 GtCO₂eq annual emissions reductions attributed to green bonds represent approximately 4 to 7% of global annual fossil fuel emissions. While this is a significant contribution, it is insufficient to meet internationally agreed global climate goals. This figure therefore highlights both the significant potential and inherent limitations of market-based instruments for transformational climate action.

The connection with the Sustainable Development Goals reveals inherent tensions that transcend technical considerations to reflect conceptual contradictions in sustainable development frameworks. In particular, the results demonstrate that the differential contribution of instruments to SDG 7 versus SDG 13 is not simply a matter of technical design; rather, it reflects fundamental trade-offs between economic efficiency and distributive equity that international frameworks tend to minimize conceptually.

Green bonds have proven effective in technological scaling and private capital mobilization, contributing significantly to SDG 13 through estimated emissions reductions of 2.1 to 3.4 GtCO₂eq annually during the period analyzed [62]. However, their contribution to universal energy access remains marginal. This disconnect suggests the need to rethink conceptual frameworks that assume automatic complementarity between climate and development goals.

4.4. Emerging Instruments and Research Gaps

With regard to hybrid instruments and green fintech applications that are underrepresented in the literature, it is useful to provide concrete examples in order to make these gaps more tangible. In this sense, hybrid instruments combine elements of different financial mechanisms: green bonds with public guarantees that reduce risks for private investors, or rural subsidy schemes integrated with carbon market elements to generate additional revenue.

Similarly, green FinTech applications include digital platforms for solar micro-payments in rural communities, blockchain systems for transparent renewable energy certification, and mobile applications for distributed financing of community energy projects. These emerging instruments could address critical constraints on access to traditional financial services in emerging economies, but their absence in the literature reflects both technological novelty and evaluative complexity.

In contrast, direct subsidies and preferential tariffs show superior effectiveness for SDG 7 in rural and decentralized contexts, facilitating energy connections for approximately 45 million people during the decade analyzed according to the studies included. However, they have fiscal sustainability limitations that compromise their long-term contribution to SDG 13 [39]. This temporal tension between immediate impacts and systemic sustainability reflects deeper limitations in evaluation frameworks that prioritize short-term results over necessary structural transformations.

4.5. Implications for Public Policy Design

The methodological limitations identified transcend technical considerations to reveal paradigmatic weaknesses in green finance research. In particular, the predominance of descriptive designs (68%) and the absence of rigorous longitudinal evaluation (8% with ≥ 5 years of follow-up) are not simply minor methodological limitations. Rather, they reflect the inadequacy of evaluation frameworks developed for stable contexts to realities characterized by institutional volatility and rapid structural transformation.

Furthermore, the absence of studies that implement rigorous causal identification through regulatory discontinuities or random assignment reflects both limitations in research capabilities and data access constraints that characterize research in emerging economies.

For policymakers in emerging economies, this review suggests specific and sequential recommendations. First, start with less institutionally complex instruments: direct subsidies targeted at rural electrification and preferential tariffs for distributed generation, before implementing sophisticated market mechanisms such as carbon markets or structurally complex green bonds.

Second, prioritize the development of basic institutional capacities, coherent regulatory frameworks, reliable monitoring systems, and technical verification capabilities as fundamental prerequisites for advanced instruments. Third, design blended financing strategies that combine public and private resources, reducing perceived risks for investors while maintaining explicit social equity objectives.

The evidence underscores that the effectiveness of green finance instruments transcends purely technical and economic considerations and depends critically on institutional quality, implementation capacities, and political economic considerations that determine the sustainability of long-term interventions [37]. This implies that public policies should prioritize institutional capacity building as a prerequisite for the successful deployment of sophisticated financial mechanisms in emerging economies.

The findings suggest the need to reorient the research agenda toward analytical frameworks that integrate considerations of political economy, institutional sustainability, and distributional dimensions that dominant technical–economic approaches tend to marginalize. Consequently, future research should prioritize the development of methodologies specifically designed to evaluate instruments in contexts characterized by high economic informality, limited institutional capacities, and macroeconomic volatility, recognizing that the direct transfer of methodological frameworks developed in advanced economies can generate systematically biased conclusions about instrumental effectiveness in emerging contexts.

5. Conclusions

This systematic review satisfactorily fulfills the overall objective of identifying, analyzing, and synthesizing the available evidence on the effectiveness of green finance instruments for the deployment of renewable energy in emerging economies, revealing a diverse but methodologically fragmented instrumental architecture that requires critical academic and policy attention.

The systematic mapping of green economic instruments shows that green bonds have emerged as the most studied and documented mechanism, demonstrating a proven ability to reduce financing costs and facilitate access to international capital markets. This predominance is particularly notable in Asian economies such as China and India, where they have been integrated as central components of national energy policies.

In parallel, direct subsidies and green tax incentives show greater effectiveness in rural and decentralized contexts, contributing significantly to universal energy access; however, they have fiscal sustainability limitations that compromise their long-term viability. Multilateral climate funds, meanwhile, demonstrate differential effectiveness depending on national institutional capacities, showing a greater contribution to adaptation projects with renewable components [37]. Likewise, carbon pricing mechanisms, despite their methodological sophistication, show limited applicability in contexts characterized by high economic informality and fragmented regulatory frameworks [36].

This instrumental differentiation suggests that there is no single model of effectiveness; rather, the results depend critically on the alignment between the characteristics of the instruments and the specific contextual conditions of each emerging economy.

5.1. Methodological Limitations and Future Research Agenda

The critical assessment of methodological quality reveals systematic limitations that compromise the robustness of the available evidence to guide policy decisions based on rigorous evidence. In particular, the predominance of descriptive designs in 68% of the included studies prevents the establishment of rigorous causal relationships between renewable deployment instruments and observed outcomes. At the same time, the absence of longitudinal evaluation in 92% of cases limits the understanding of the sustainability of impacts and general equilibrium effects that emerge over time.

The extreme heterogeneity in outcome measures used and the analytical fragmentation that examines instruments in isolation represent additional obstacles to the development of comparative frameworks to guide the optimal selection of mechanisms according to specific contextual characteristics. These limitations are not simply minor technical shortcomings, but reflect the absence of sufficiently robust conceptual frameworks to address the inherent complexity of the energy transition in diverse institutional contexts.

Consequently, the knowledge gaps identified reveal a critical underrepresentation of hybrid instruments, digital financial technological applications, and systematic analysis of distributional dimensions. These limitations are particularly problematic considering that these elements may be determinants of energy transition success in emerging contexts characterized by high structural inequalities and limited access to traditional financial services.

Geographically, the concentration of evidence in East Asia and the underrepresentation of sub-Saharan Africa, Central Asia, and small island developing states compromise the applicability of findings to diverse institutional and socioeconomic contexts that represent a significant proportion of the global population.

5.2. Practical Implications for Policymakers

The findings of this review have significant practical utility for policymakers by demonstrating that the direct transfer of instruments from advanced economies has substantial limitations. Consequently, careful contextual adaptations are required that consider differences in market structures, institutional capacities, and specific socioeconomic characteristics [37].

The differential contribution of instruments to SDG 7 versus SDG 13 suggests the need to develop monitoring frameworks that explicitly assess tensions between economic efficiency and distributive equity. This assessment should recognize that the simultaneous achievement of universal energy access and emissions reductions requires comprehensive strategies that combine multiple instruments according to specific contexts, rather than relying on uniform solutions applied universally.

In terms of relevance to the Sustainable Development Goals, evidence underscores that the effectiveness of green finance instruments transcends purely technical and economic considerations. On the contrary, it critically depends on institutional quality, implementation capacities, and political economic considerations that determine the sustainability of long-term interventions [39,62]. This implies that public policies should prioritize institutional capacity building as a fundamental prerequisite for the successful deployment of sophisticated financial mechanisms in emerging economies.

5.3. Specific Recommendations and Future Directions

For emerging economies seeking to implement green finance instruments, this research recommends adopting gradual and contextualized approaches. Initially, it is prudent to

prioritize less institutionally complex instruments: targeted subsidies for rural electrification and preferential tariff schemes for distributed generation, before moving toward sophisticated market mechanisms that require advanced institutional capacities.

At the same time, it is essential to invest in basic institutional capacity building, robust regulatory frameworks, reliable monitoring systems, and local technical capabilities as a foundation for more advanced instruments. This sequencing recognizes that the effectiveness of sophisticated financial mechanisms depends critically on the existence of institutions capable of implementing and supervising them adequately.

The design of instruments should explicitly address social equity considerations, given that the mechanisms analyzed tend to disproportionately benefit agents with greater financial capacity, potentially exacerbating existing inequalities in the energy transition. This consideration is particularly relevant in contexts where energy access gaps coincide with pre-existing socioeconomic inequalities.

Future research should prioritize the development of comparative cost-effectiveness frameworks between instruments, longitudinal studies that assess the sustainability of impacts beyond immediate time horizons, and methodologies specifically designed for contexts of high informality and limited institutional capacities. These research priorities reflect the limitations identified in the existing literature and the practical needs of policymakers.

In particular, the emerging research agenda should incorporate a systematic analysis of hybrid instruments and applications of digital financial technology, recognizing their transformative potential to democratize access to green finance for populations traditionally excluded from formal financial services. Geographically, it is imperative to expand the evidence base to underrepresented regions, particularly sub-Saharan Africa, Central Asia, and small island states, to develop more inclusive and globally applicable policy frameworks.

This research makes three original theoretical contributions to the field of green finance that transcend the descriptive inventory prevalent in the literature. First, the Integrated Institutional Capacity Framework (MICI-FV), derived from the systematic synthesis of empirical evidence analyzed [34–37], provides a predictive tool for assessing the ex ante feasibility of instruments according to contextual institutional profiles, overcoming ad hoc approaches that characterize current practice. Second, the identification of epistemic fragmentation through bibliometric analysis [42] explains the theoretical limitations of the field and provides a basis for future conceptual integration. Third, the concept of a “minimum institutional capacity threshold”, emerging from the analysis of documented patterns of differential effectiveness, offers operational criteria for designing gradual implementation trajectories that respect structural constraints while progressively developing capacities.

These contributions challenge fundamental assumptions about the universal transferability of financial instruments evidenced in the reviewed literature and establish theoretical foundations for contextually sensitive approaches that recognize structural heterogeneities among emerging economies that have been systematically documented [39,59,62]. Methodologically, the integration of bibliometric analysis with a systematic review according to the PRISMA guidelines [31] reveals epistemic dynamics that compromise knowledge accumulation, providing foundations for reconceptualization of the field toward more integrative frameworks that articulate the fragmented perspectives identified in the analyzed literature.

Finally, this review confirms that sustainable energy transition in emerging economies requires more than technically sophisticated financial instruments: it demands comprehensive approaches that combine financial innovation with institutional strengthening, social equity considerations, and careful contextual adaptation. Future success will depend not only on the availability of green capital but also on the ability of these countries to develop financial and regulatory ecosystems that effectively channel these resources toward just and sustainable energy transformations that benefit the entire population.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/en18174560/s1>, File S1: PRISMA statement. Reference [31] is cited in the Supplementary Files.

Author Contributions: Conceptualization, E.V.R.F. and G.S.L.-R.; methodology, E.V.R.F. and L.A.V.Z.; software, L.E.C.S. and P.V.Z.; validation, G.C.F.C. and L.A.V.Z.; formal analysis, G.C.F.C. and G.S.L.-R.; investigation, E.V.R.F.; resources, L.E.C.S.; data curation, L.K.C.C.; writing—original draft preparation, G.C.F.C., L.A.V.Z. and G.S.L.-R.; writing—review and editing, L.C.R. and L.K.C.C.; visualization, L.E.C.S.; supervision, L.C.R. and L.K.C.C.; project administration, L.C.R. and P.V.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Njangang, H.; Padhan, H.; Tiwari, A.K. From Aid to Resilience: Assessing the Impact of Climate Finance on Energy Vulnerability in Developing Countries. *Energy Econ.* **2024**, *134*, 107595. [[CrossRef](#)]
2. Zhou, K.; Li, Y. Carbon Finance and Carbon Market in China: Progress and Challenges. *J. Clean. Prod.* **2019**, *214*, 536–549. [[CrossRef](#)]
3. Cui, L.; Huang, Y. Exploring the Schemes for Green Climate Fund Financing: International Lessons. *World Dev.* **2018**, *101*, 173–187. [[CrossRef](#)]
4. Jawadi, F.; Pondie, T.M.; Cheffou, A.I. New Challenges for Green Finance and Sustainable Industrialization in Developing Countries: A Panel Data Analysis. *Energy Econ.* **2025**, *142*, 108120. [[CrossRef](#)]
5. Zhang, D.; Zhang, Z.; Managi, S. A Bibliometric Analysis on Green Finance: Current Status, Development, and Future Directions. *Financ. Res. Lett.* **2019**, *29*, 425–430. [[CrossRef](#)]
6. Pang, L.; Zhu, M.N.; Yu, H. Is Green Finance Really a Blessing for Green Technology and Carbon Efficiency? *Energy Econ.* **2022**, *114*, 106272. [[CrossRef](#)]
7. Song, C.; Wu, Z.; Dong, R.K.; Dinçer, H. Greening South Asia: Investing in Sustainability and Innovation to Preserve Natural Resources and Combat Environmental Pollution. *Resour. Policy* **2023**, *86*, 104239. [[CrossRef](#)]
8. Le, T.-H.; Nguyen, C.P.; Park, D. Financing Renewable Energy Development: Insights from 55 Countries. *Energy Res. Soc. Sci.* **2020**, *68*, 101537. [[CrossRef](#)]
9. Seminario-Córdova, R. Latin America towards Sustainability through Renewable Energies: A Systematic Review. *Energies* **2023**, *16*, 7422. [[CrossRef](#)]
10. Fleta-Asín, J.; Muñoz, F. Renewable Energy Public–Private Partnerships in Developing Countries: Determinants of Private Investment. *Sustain. Dev.* **2021**, *29*, 653–670. [[CrossRef](#)]
11. Paraque, B.; Revelli, C. Ethico-Economic Analysis of Impact Finance: The Case of Green Bonds. *Res. Int. Bus. Financ.* **2019**, *47*, 57–66. [[CrossRef](#)]
12. Liu, S.; Qi, H.; Wan, Y. Driving Factors behind the Development of China’s Green Bond Market. *J. Clean. Prod.* **2022**, *354*, 131705. [[CrossRef](#)]
13. Fu, J.; Ng, A.W. Scaling up Renewable Energy Assets: Issuing Green Bond via Structured Public-Private Collaboration for Managing Risk in an Emerging Economy. *Energies* **2021**, *14*, 3076. [[CrossRef](#)]
14. Yoshino, N.; Taghizadeh-Hesary, F.; Nakahigashi, M. Modelling the Social Funding and Spill-over Tax for Addressing the Green Energy Financing Gap. *Econ. Model.* **2019**, *77*, 34–41. [[CrossRef](#)]
15. Kilinc-Ata, N.; Proskuryakova, L.N. The Contribution of Energy Policies to Green Energy Transition in the Asia-Pacific Region. *Renew. Energy* **2024**, *237*, 121797. [[CrossRef](#)]
16. Flaherty, M.; Gevorkyan, A.; Radpour, S.; Semmler, W. Financing Climate Policies through Climate Bonds—A Three Stage Model and Empirics. *Res. Int. Bus. Financ.* **2017**, *42*, 468–479. [[CrossRef](#)]
17. Warren, P. Blind Spots in Climate Finance for Innovation. *Adv. Clim. Change Res.* **2020**, *11*, 60–64. [[CrossRef](#)]
18. Zahid, H.; Zulfiqar, A.; Adnan, M.; Iqbal, M.S.; Shah, A.; Mohamed, S.E.G. Global Renewable Energy Transition: A Multidisciplinary Analysis of Emerging Computing Technologies, Socio-Economic Impacts, and Policy Imperatives. *Results Eng.* **2025**, *26*, 105258. [[CrossRef](#)]
19. Gareth, B.; Webber, S. *Climate Finance: Taking a Position on Climate Futures*; Agenda Publishing: Newcastle upon Tyne, UK, 2024; ISBN 978-1-78821-462-9.

20. Kiefer, C.P.; del Río, P. Analysing the Impact of Renewable Energy Auctions on Market Concentration. *Renew. Energy* **2024**, *221*, 119664. [CrossRef]
21. Parés, F.; Busch, P. *Renewable Energy and Energy Storage Value Chains in Latin America and the Caribbean*; IDB Publication: Washington, DC, USA, 2024. [CrossRef]
22. Liu, C.; Wu, S.S. Green Finance, Sustainability Disclosure and Economic Implications. *Fulbright Rev. Econ. Policy* **2023**, *3*, 1–24. [CrossRef]
23. Alex-Oke, T.; Bamisile, O.; Cai, D.; Adun, H.; Ukwuoma, C.C.; Tenebe, S.A.; Huang, Q. Renewable Energy Market in Africa: Opportunities, Progress, Challenges, and Future Prospects. *Energy Strategy Rev.* **2025**, *59*, 101700. [CrossRef]
24. Gallagher, K.P.; Kamal, R.; Jin, J.; Chen, Y.; Ma, X. Energizing Development Finance? The Benefits and Risks of China's Development Finance in the Global Energy Sector. *Energy Policy* **2018**, *122*, 313–321. [CrossRef]
25. Meng, B.; Liu, Y.; Gao, Y.; Li, M.; Wang, Z.; Xue, J.; Andrew, R.; Feng, K.; Qi, Y.; Sun, Y.; et al. Las Responsabilidades de Los Países En Desarrollo Por Las Emisiones de CO₂ En Las Cadenas de Valor Son Mayores y Crecen Más Rápido Que Las de Los Países Desarrollados. *One Earth* **2023**, *6*, 167–181. [CrossRef]
26. Naeem, M.A.; Karim, S.; Rabbani, M.R.; Bashir, A.; Kumar, S. Current State and Future Directions of Green and Sustainable Finance: A Bibliometric Analysis. *Qual. Res. Financ. Mark.* **2022**, *15*, 608–629. [CrossRef]
27. Tanveer, B.; Iftikhar, K. Green Finance Perspective: Understanding the Theoretical Context, Circular Economy, and Culminating Political Processes. Available online: https://www.researchgate.net/publication/379988441_Green_finance_perspective_Understanding_the_Theoretical_Context_Circular_Economy_and_Culminating_Political_Processes (accessed on 25 May 2025).
28. White, S.J.; Sin, J.; Sweeney, A.; Salisbury, T.; Wahlich, C.; Montesinos Guevara, C.M.; Gillard, S.; Brett, E.; Allwright, L.; Iqbal, N.; et al. Global Prevalence and Mental Health Outcomes of Intimate Partner Violence Among Women: A Systematic Review and Meta-Analysis. *Trauma Violence Abus.* **2024**, *25*, 494–511. [CrossRef] [PubMed]
29. Chen, J.M.; Umair, M.; Hu, J. Green Finance and Renewable Energy Growth in Developing Nations: A GMM Analysis. *Heliyon* **2024**, *10*, e33879. [CrossRef] [PubMed]
30. Haasnoot, M.; Di Fant, V.; Kwakkel, J.; Lawrence, J. Lessons from a Decade of Adaptive Pathways Studies for Climate Adaptation. *Glob. Environ. Change* **2024**, *88*, 102907. [CrossRef]
31. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
32. Stojan, B. Green Economy and Green Finance as a Contribution to Sustainable Green Activities at the Global Level. In *Reference Module in Social Sciences*; Elsevier: Amsterdam, The Netherlands, 2023; ISBN 978-0-443-15785-1.
33. Babic, M. Green Finance in the Global Energy Transition: Actors, Instruments, and Politics. *Energy Res. Soc. Sci.* **2024**, *111*, 103482. [CrossRef]
34. Zhou, M.; Li, X. Influence of Green Finance and Renewable Energy Resources over the Sustainable Development Goal of Clean Energy in China. *Resour. Policy* **2022**, *78*, 102816. [CrossRef]
35. Alharbi, S.S.; Al Mamun, M.; Boubaker, S.; Rizvi, S.K.A. Green Finance and Renewable Energy: A Worldwide Evidence. *Energy Econ.* **2023**, *118*, 106499. [CrossRef]
36. Hassan, T.; Khan, Y.; Safi, A.; Chaolin, H.; Wahab, S.; Daud, A.; Tufail, M. Green Financing Strategy for Low-Carbon Economy: The Role of High-Technology Imports and Institutional Strengths in China. *J. Clean. Prod.* **2023**, *415*, 137859. [CrossRef]
37. Lee, C.-C.; Li, X.; Yu, C.-H.; Zhao, J. The Contribution of Climate Finance toward Environmental Sustainability: New Global Evidence. *Energy Econ.* **2022**, *111*, 106072. [CrossRef]
38. Yu, H.; Wei, W.; Li, J.; Li, Y. The Impact of Green Digital Finance on Energy Resources and Climate Change Mitigation in Carbon Neutrality: Case of 60 Economies. *Resour. Policy* **2022**, *79*, 103116. [CrossRef]
39. Ibrahim, D.M.; Esily, R.R.; Sameh, R. Climate Change and Green Finance: The Role of Central Banks. In *Reference Module in Social Sciences*; Elsevier: Amsterdam, The Netherlands, 2023; ISBN 978-0-443-15785-1.
40. Bhattacharya, C.B.; Korschun, D.; Sen, S. Strengthening Stakeholder–Company Relationships Through Mutually Beneficial Corporate Social Responsibility Initiatives. *J. Bus. Ethics* **2009**, *85* (Suppl. S2), 257–272. [CrossRef]
41. United Nations The Paris Agreement | UNFCCC. Available online: <https://unfccc.int/process-and-meetings/the-paris-agreement> (accessed on 25 May 2025).
42. Aria, M.; Cuccurullo, C. *Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis*. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
43. Committee on Publication Ethics. Committee on Publication Ethics (COPE): Guidelines on Good Publication Practice. *Clin. Oncol.* **2000**, *12*, 206–212. [CrossRef]
44. Ruan, Q.; Li, C.; Lv, D.; Wei, X. Going Green: Effect of Green Bond Issuance on Corporate Debt Financing Costs. *N. Am. J. Econ. Financ.* **2025**, *75*, 102299. [CrossRef]

45. Schwerhoff, G.; Sy, M. Financing Renewable Energy in Africa—Key Challenge of the Sustainable Development Goals. *Renew. Sustain. Energy Rev.* **2017**, *75*, 393–401. [[CrossRef](#)]
46. Can, U.; Gizem, Z. Financing or Taxation? Assessing the Effectiveness of Carbon Emissions Reduction Programs. *Borsa Istanbul Review* **2025**, *25*, 700–708. [[CrossRef](#)]
47. Sarto, N.D.; Ozili, P.K. FinTech and Financial Inclusion in Emerging Markets: A Bibliometric Analysis and Future Research Agenda. *Int. J. Emerg. Mark.* **2025**, *20*, 270–290. [[CrossRef](#)]
48. De Grefte, J.; de Bruin, B. Sustainable Finance, Biodiversity, and Greenwashing: How Contested Values, Metrics, and Causation Facilitate Information Distortion, Information Omission, and Information Pollution. *Curr. Opin. Environ. Sustain.* **2025**, *74*, 101522. [[CrossRef](#)]
49. Mazzucato, M.; Semieniuk, G. Financing Renewable Energy: Who Is Financing What and Why It Matters. *Technol. Forecast. Soc. Change* **2018**, *127*, 8–22. [[CrossRef](#)]
50. Bocchialini, E.; Ferretti, P.; Ielasi, F. Pension Plans’ Sustainable Identity as a Catalyst for Environmental and Social Investing. *Environ. Impact Assess. Rev.* **2025**, *110*, 107702. [[CrossRef](#)]
51. Polzin, F.; Egli, F.; Steffen, B.; Schmidt, T.S. How Do Policies Mobilize Private Finance for Renewable Energy?—A Systematic Review with an Investor Perspective. *Appl. Energy* **2019**, *236*, 1249–1268. [[CrossRef](#)]
52. Hu, D.; Gan, C. Green Finance Development and Its Origin, Motives, and Barriers: An Exploratory Study. *Environ. Dev. Sustain.* **2025**. [[CrossRef](#)]
53. Raikar, S.; Adamson, S. Renewable Energy Finance in the International Context. In *Renewable Energy Finance*; Raikar, S., Adamson, S., Eds.; Academic Press: Cambridge, MA, USA, 2020; pp. 185–220, ISBN 978-0-12-816441-9.
54. Imandojemu, K. Green Finance and Environmental Quality in Emerging Market and Developing Economies. *Energy Res. Lett.* **2025**, *6*. [[CrossRef](#)]
55. Bhattacharyya, R. Enabling the Clean Energy Transition: An Assessment of the Role of Sustainable and Green Finance Taxonomies. In *Reference Module in Social Sciences*; Elsevier: Amsterdam, The Netherlands, 2023; ISBN 978-0-443-15785-1.
56. Liu, Y.; Dong, K.; Wang, K.; Taghizadeh-Hesary, F. Moving towards Sustainable City: Can China’s Green Finance Policy Lead to Sustainable Development of Cities? *Sustain. Cities Soc.* **2024**, *102*, 105242. [[CrossRef](#)]
57. Chen, J.; Meng, W.; Chen, Y.; Zhou, W. To Be an Eco- and Tech-Friendly Society: Impact Research of Green Finance on AI Innovation. *J. Clean. Prod.* **2024**, *466*, 142900. [[CrossRef](#)]
58. Qing, L.; Abbas, J.; Najam, H.; Ma, X.; Dagestani, A. Investment in Renewable Energy and Green Financing and Their Role in Achieving Carbon-Neutrality and Economic Sustainability: Insights from Asian Region. *Renew. Energy* **2024**, *221*, 119830. [[CrossRef](#)]
59. Mohsin, M.; Jamaani, F. Unfolding Impact of Natural Resources, Economic Growth, and Energy Nexus on the Sustainable Environment: Guidelines for Green Finance Goals in 10 Asian Countries. *Resour. Policy* **2023**, *86*, 104238. [[CrossRef](#)]
60. Chen, K.; Bian, R. Green Financing and Renewable Resources for China’s Sustainable Growth: Assessing Macroeconomic Industry Impact. *Resour. Policy* **2023**, *85*, 103927. [[CrossRef](#)]
61. Madaleno, M.; Dogan, E.; Taskin, D. A Step Forward on Sustainability: The Nexus of Environmental Responsibility, Green Technology, Clean Energy and Green Finance. *Energy Econ.* **2022**, *109*, 105945. [[CrossRef](#)]
62. Taneja, S.; Bhatnagar, M.; Ozen, E. Greening the Economy: Harnessing the Power of Sustainable Finance. In *Reference Module in Social Sciences*; Elsevier: Amsterdam, The Netherlands, 2023; ISBN 978-0-443-15785-1.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.