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Green Digital Transformation, Green Innovation, and Green Performance: A Bibliometric Review and Integrative Research Agenda

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ABSTRACT

The convergence of digital transformation and environmental sustainability has created a rapidly expanding but fragmented research domain spanning digitalization, green innovation, environmental regulation, green finance, and firm performance. This review maps the intellectual and thematic structure of this domain and develops an integrative research agenda. A bibliometric dataset of 341 Web of Science articles published in 2022–2026, retrieved with the query "Green digital transformation" OR "Green innovation" OR "green performance" and restricted to Business and Management categories and SDG 12, was analysed with Biblioshiny/Bibliometrix through performance analysis, keyword and trend-topic analysis, co-word networks, co-citation, and collaboration mapping. The corpus spans 70 sources and 18,154 cited references and averages 34.17 citations per document. Green innovation is the dominant organizing concept, while performance, environmental regulation, digital transformation, green finance, and circular economy connect technological, organizational, financial, and policy streams. China accounts for 73.6% of corresponding-author publications, providing a rich empirical setting but limiting generalizability. The review synthesizes the field into an input–capability–innovation–performance architecture in which digital transformation enables information processing and resource reconfiguration, organizational capabilities convert these affordances into green innovation, and institutional and financial conditions shape the strength of these pathways. Future research should move beyond direct-effect models toward longitudinal, cross-country, multilevel, and configurational designs that distinguish forms of green innovation and use objective environmental outcomes. The study contributes a reproducible knowledge map and a theory-oriented framework for digital–green transformation research.

Keywords: Green digital transformation, Green innovation, Green performance, Bibliometric analysis, Biblioshiny, Digital transformation.

Introduction

Digital transformation and environmental sustainability are increasingly treated as interdependent strategic challenges rather than separate managerial agendas. Digital technologies can improve visibility, coordination, prediction, automation, and resource allocation, while environmental strategies require firms to redesign products, processes, supply chains, and governance routines to reduce ecological burdens. The emerging literature therefore asks not only whether digitalization improves business outcomes, but also whether and under what conditions it supports green innovation and measurable environmental performance. Recent studies in the corpus examine, for example, how enterprise digital transformation promotes green technology innovation through financing constraints and under policy uncertainty, and how digital–real integration improves green governance performance through productivity and green innovation mechanisms (Wang *et al*., 2024; Lu *et al*., 2026). These studies illustrate a broader transition from technology-centered digitalization toward digitally enabled sustainable value creation.

The field is nevertheless conceptually dispersed. "Green innovation" is used as an umbrella for product, process, technological, exploratory, exploitative, and organizational innovation; "green performance" may refer to

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environmental, innovation, governance, operational, or broader sustainability outcomes; and "green digital transformation" can denote either the greening of digital activities or the use of digital capabilities to accelerate environmental transformation. This heterogeneity makes cumulative theory building difficult. It also increases the risk that statistically significant relationships are interpreted as evidence of sustainability without specifying the environmental mechanism or outcome. A state-of-the-art review is therefore needed to identify the field's intellectual anchors, thematic clusters, empirical concentration, and unresolved causal mechanisms.

Existing studies indicate that the digital–green relationship is rarely a simple technology-to-performance path. Digital transformation may relax information and financing constraints, strengthen knowledge recombination, improve monitoring, enable cleaner production, or facilitate green innovation; however, these benefits depend on organizational capabilities, market institutions, managerial cognition, regulatory pressure, and financial support. Evidence also differentiates forms of green innovation. Liu *et al*. (2025), for example, show that green subsidies and effluent charges motivate different exploratory and exploitative innovation responses, while Perotti *et al*. (2025) connect green and open innovation with circular-economy implementation (Wright & Matthews, 2025). Such findings suggest that the literature is moving from a direct-effect logic toward a contingent capability-based explanation.

A bibliometric review is appropriate for this purpose because it combines performance analysis with science mapping. Performance indicators reveal productive sources, influential documents, countries, and authors; co-word analysis identifies the conceptual structure expressed through keywords; co-citation reveals the knowledge bases that later studies draw upon; and collaboration analysis shows how knowledge production is geographically and socially organized. Used together with qualitative interpretation, these techniques can answer not merely "who publishes most?" but "how is the field structured, what mechanisms dominate, and where should theory move next?" (Aria & Cuccurullo, 2017; Donthu *et al*., 2021; Al-Farsi *et al*., 2026).

Accordingly, this review addresses four questions: RQ1, how has recent research on green digital transformation, green innovation, and green performance developed in terms of sources, authors, countries, and citation influence? RQ2: What conceptual and intellectual structures organize the field? RQ3: Which themes are mature, emerging, or weakly integrated? RQ4: What research agenda can better explain how digital transformation is converted into green innovation and green performance? By answering these questions, the review contributes an evidence-based map of a fast-growing domain, highlights geographic and conceptual imbalances, and proposes an integrative input–capability–innovation–performance framework suitable for future empirical testing.

Materials and Methods

Review Design and Data Source

The study followed a bibliometric review design combining descriptive performance analysis, science mapping, and interpretive synthesis. Web of Science was used as the bibliographic source because the search was explicitly refined by Web of Science indexes and categories, and the exported records contain standardized cited-reference and affiliation fields required for network analysis. The final export contained 341 records. The analysis was conducted with Biblioshiny, the web interface of the Bibliometrix R package, which supports reproducible bibliometric workflows and integrates source, author, country, keyword, co-citation, and collaboration analyses (Aria & Cuccurullo, 2017; Mohammad *et al*., 2024).

Search Strategy and Eligibility Criteria

The search expression was ("Green digital transformation" OR "Green innovation" OR "green performance"). The search interface was refined to publication years 2022, 2023, 2024, 2025, or 2026; document type: Article; Web of Science categories: Business or Management; and Web of Science indexes: SSCI, SCI-EXPANDED, or ESCI. Publisher filters included Wiley, Emerald Group Publishing, Taylor & Francis, Elsevier, Springer Nature, Sage, Inderscience Enterprises Ltd, World Scientific, KeAi Publishing Ltd, and Walter de Gruyter. The search was additionally restricted to Sustainable Development Goal 12, Responsible Consumption and Production. These filters intentionally prioritize recent management and business scholarship relevant to responsible production rather than attempting to represent every engineering or environmental-science publication using the same terminology.

A data-quality note is necessary. Although the search interface specified 2022–2026, the Biblioshiny Main Information sheet reports the timespan as 2022:2027 and the raw export contains two records indexed as 2027. The available export does not establish whether these records reflect early-access assignment, indexing updates, or another Web of Science metadata process. Therefore, the review treats 2022–2026 as the intended eligibility window, retains the 341-record exported corpus for reproducibility, and avoids interpreting the two 2027-indexed records as evidence of a completed 2027 publication year. This discrepancy should be rechecked in Web of Science immediately before submission.

Bibliometric Indicators and Analytical Procedure

The analysis proceeded in three layers. First, performance analysis described the corpus through the number of sources and documents, average citations, reference count, productive journals and authors, corresponding-author countries, and globally and locally cited works. Second, conceptual structure was examined through keyword frequency, trend topics, and co-word networks. In the co-word network, betweenness indicates the extent to which a term bridges otherwise separated thematic areas, closeness reflects proximity to other nodes, and PageRank captures structural prominence. Third, intellectual and social structures were examined through co-citation and collaboration networks. Thematic-map outputs were interpreted as evidence of topic development rather than as causal results.

The bibliometric outputs were then read qualitatively to construct an integrative synthesis. This step is essential because frequency alone cannot determine theoretical meaning. High-frequency terms were linked to representative documents and established theoretical traditions, including the Porter hypothesis, resource-based reasoning, eco-innovation, financing constraints, environmental regulation, and digital capability perspectives. Claims about causal mechanisms were restricted to what representative empirical studies report; broader connections proposed by this review are identified as integrative interpretations rather than direct findings from the bibliometric software.

Results and Discussion

Descriptive Profile of the Knowledge Base

The 341-document corpus is distributed across 70 sources and cites 18,154 references **(Table 1)**. Biblioshiny reports 1,044 author keywords and 609 Keywords Plus terms, indicating substantial lexical diversity despite the relatively narrow five-year search window. Average citations per document are 34.17, which is high for a recent corpus and suggests that the topic has accumulated influence quickly. The reported annual growth rate is −38.1%; however, this statistic should not be interpreted as contraction of the field because the dataset includes incomplete/forward-indexed publication years and a concentrated recent window. Publication-year counts in the raw export are 22 (2022), 38 (2023), 82 (2024), 75 (2025), 122 (2026), and two records indexed as 2027. The pattern therefore indicates strong recent expansion, particularly in 2024–2026, rather than a mature decline.

Table 1. Main information about the dataset.

Indicator	Result
Documents	341
Sources	70
References	18,154
Average citations/document	34.17
Document average age	1.29 years
Author keywords	1,044
Keywords Plus	609
Biblioshiny-reported timespan	2022:2027*

*The intended search window was 2022–2026; see the data-quality note.

Leading Publication Outlets

Publication activity is highly concentrated in a small set of management, innovation, and sustainability journals. Technological Forecasting and Social Change leads with 61 articles **(Table 2)**, followed by Business Strategy and the

Environment (41), Emerging Markets Finance and Trade (33), Technology Analysis & Strategic Management (32), Managerial and Decision Economics (22), and Journal of Innovation & Knowledge (21). This distribution is theoretically informative. The field is not located solely in environmental-management outlets; instead, it is embedded in technology forecasting, strategy, finance, innovation, and knowledge-management conversations. This cross-journal pattern helps explain why digital transformation, financing constraints, environmental regulation, and innovation capability appear as recurring mechanisms.

Table 2. Most relevant publication sources.

Source	Articles
Technological Forecasting and Social Change	61
Business Strategy and the Environment	41
Emerging Markets Finance and Trade	33
Technology Analysis & Strategic Management	32
Managerial and Decision Economics	22
Journal of Innovation & Knowledge	21
Corporate Social Responsibility and Environmental Management	14
Technovation	6
Journal of Technology Transfer	5
Chinese Management Studies	4
Journal of Knowledge Management	4

Authors and Geographic Structure

The author distribution is comparatively dispersed. In the Biblioshiny author ranking, C. P. Chang is the most productive author with six articles, Y. Hao has five, and X. Y. Chen, J. Wen, H. T. Wu, A. T. Xu, B. Zhou, and Y. H. Zhu each have four. The limited absolute counts among leading authors suggest a rapidly developing field with many research teams rather than a small closed core of recurring scholars. Geographic concentration is much stronger. China contributes 251 corresponding-author articles **(Table 3)**, equivalent to 73.61% of the corpus, followed by India (13), Spain (9), Italy (8), the United Kingdom (7), France (5), Pakistan (5), and Vietnam (5).

The single-country/multiple-country publication pattern adds nuance. China records 191 single-country publications and 60 multiple-country publications, giving an MCP share of 23.9%. The United Kingdom records six international collaborations among seven papers, France five among five, and Pakistan three among five. Thus, China dominates volume, whereas several European countries show higher internationalization ratios. The empirical dominance of China is understandable because Chinese firms and provinces provide rich settings for studying digitalization, green finance, environmental regulation, subsidies, and green patenting. Yet it also constitutes a major external-validity limitation. Institutional conditions in China—state ownership, industrial policy, subsidy regimes, regional digital infrastructure, and environmental regulation—cannot automatically be generalized to other emerging or developed economies.

Table 3. Leading corresponding-author countries and international collaboration.

Country	Articles	Share (%)	SCP	MCP	MCP (%)
China	251	73.61	191	60	23.90
India	13	3.81	11	2	15.38
Spain	9	2.64	7	2	22.22
Italy	8	2.35	5	3	37.50
United Kingdom	7	2.05	1	6	85.71
France	5	1.47	0	5	100
Pakistan	5	1.47	2	3	60.00
Vietnam	5	1.47	5	0	0

Citation Structure and Influential Contributions

The most globally cited documents reveal the intellectual acceleration of the field. Luo *et al*. (2023) in Business Strategy and the Environment records 710 citations, while Irfan *et al*. (2022) in Technological Forecasting and Social Change records 704. Other highly cited contributions include Lian *et al*. (2022), Kong *et al*. (2022), Cui *et al*. (2022), Zhao *et al*. (2022), Xu *et al*. (2023), and Sun *et al*. (2024) **(Table 4)**. Because citation counts are time-dependent, raw totals should be read alongside citations per year and normalized citation scores (Meyer *et al*., 2025). Sun *et al*. (2024), for example, combines a lower raw total than the 2022–2023 leaders with a high normalized score, indicating rapid uptake relative to its publication cohort.

Table 4. Selected globally cited documents.

Document	Total citations	TC/year	Normalized TC
Luo *et al*. (2023), BSE	710	177.5	7.34
Irfan *et al*. (2022), TFSC	704	140.8	4.37
Lian *et al*. (2022), JIK	343	68.6	2.13
Kong *et al*. (2022), EMFT	298	59.6	1.85
Cui *et al*. (2022), TFSC	272	54.4	1.69
Zhao *et al*. (2022), TFSC	265	53.0	1.64
Xu *et al*. (2023), JBR	239	59.8	2.47
Sun *et al*. (2024), TFSC	235	78.3	6.20

Local citations reveal a complementary intellectual base. Porter and van der Linde's environmental-innovation argument is the most locally cited reference (68 local citations), followed by Chen's green innovation work (27), Barney's resource-based view (26), and several studies on regulation, eco-innovation, finance, and green innovation. The prominence of Porter and van der Linde (1995), Chen (2006), Barney (1991), and Rennings (2000) indicates that the contemporary digital–green literature is built on an older foundation combining regulation-induced innovation, strategic resources, and eco-innovation (Chandrasekhar *et al*., 2025). Digital transformation is therefore entering an established environmental-innovation conversation rather than creating an entirely separate theoretical field.

Keyword structure: green innovation as the organizing hub

Keyword frequency provides the clearest indication of the field's conceptual center. "Green innovation" occurs 164 times, more than twice the frequency of "performance" (79) and well above "impact" (66), "China" (46), "innovation" (42), "technology" (36), "growth" (35), "management" (33), "research-and-development" (26), "sustainability" (22), and "environmental regulation" (21). Green finance and circular economy also emerge as important recent topics. This pattern shows that green innovation is not merely one outcome among many; it functions as the principal mechanism through which technological, financial, institutional, and managerial antecedents are linked to sustainability-related outcomes.

Co-word Network and Conceptual Architecture

The co-word network reinforces this interpretation **(Table 5)**. Green innovation has the highest PageRank (0.126) and by far the highest betweenness centrality (407.68), followed by performance (PageRank 0.078; betweenness 148.42) and impact (PageRank 0.065; betweenness 77.54). Digital transformation appears in the same broad cluster but with lower centrality, suggesting that it is an enabling or connecting concept rather than the historical core of the domain. Sustainability, eco-innovation, circular economy, policy, determinants, and management surround this hub. Structurally, the field can therefore be interpreted as a green-innovation-centered network in which digital transformation, finance, regulation, and organizational capabilities act as antecedent or contextual mechanisms, while performance and sustainability represent outcome families.

Table 5. Selected co-word network centrality indicators.

Node	Cluster	Betweenness	PageRank
green innovation	1	407.68	0.1259

performance	1	148.42	0.0775
impact	1	77.54	0.0650
management	1	11.16	0.0305
eco-innovation	1	4.82	0.0234
sustainability	1	4.38	0.0190
circular economy	1	1.44	0.0145
digital transformation	1	0.08	0.0092

Trend Topics and the Field's Movement toward Integration

Trend-topic results show a temporal shift from macroeconomic and constraint-oriented questions toward organizational sustainability integration. Economic growth and constraints have median topic years around 2023, whereas performance, impact, and China center around 2024. Green innovation, innovation, and management move toward 2025, while green finance and circular economy center around 2026. This progression suggests that early work in the review window concentrated on whether digital and environmental interventions influence growth and innovation, while more recent work asks how financing systems, circularity, management, and organizational mechanisms shape implementation. The shift is consistent with a maturing research field: after establishing direct associations, scholars increasingly investigate mechanisms, boundary conditions, and system-level integration.

Thematic synthesis I: digital transformation as an enabling infrastructure

The first major stream treats digital transformation as an enabling infrastructure for environmental innovation. Digital technologies can improve information availability, reduce search and coordination costs, increase process visibility, support real-time monitoring, and enable firms to identify inefficiencies that were previously hidden. Wang *et al*. (2024) report that enterprise digital transformation promotes green technology innovation and that financing constraints partially mediate this relationship; economic policy uncertainty further conditions the effect (Temirbekova *et al*., 2024). Zhao and Fang (2025) similarly find that digital transformation improves green innovation performance, with mechanisms involving green technological progress and green financial development. Lu *et al*. (2026) extend the logic to green governance performance, identifying total factor productivity and green innovation as mediating mechanisms and executives' green cognition, employee green digital literacy, and environmental regulation as moderators (Naseri & Sasani, 2024).

These findings challenge a technologically deterministic view. Digital investment alone does not constitute green transformation. Digitalization creates an information-processing and coordination infrastructure, but environmental value emerges when firms direct that infrastructure toward green search, experimentation, resource efficiency, emissions management, or governance improvement. Future studies should therefore measure the "green directionality" of digital transformation rather than assuming that general digital intensity is environmentally beneficial. This distinction is especially important because digital technologies also consume energy and may create rebound effects.

Thematic Synthesis II: Green Innovation as the Conversion Mechanism

The second stream positions green innovation as the conversion mechanism between organizational inputs and green outcomes. Green innovation encompasses product, process, technological, exploratory, exploitative, and business-model changes that reduce environmental burdens or improve resource efficiency. The bibliometric dominance of the term, combined with its network centrality, supports treating it as the field's main mediating architecture. Studies increasingly differentiate innovation types rather than treating green innovation as a single homogeneous construct. Liu *et al*. (2025) demonstrate that green subsidies are more strongly associated with exploratory green innovation, whereas effluent charges are more likely to encourage exploitative green innovation (Collins *et al*., 2025). Perotti *et al*. (2025) show that green product and process innovation can support circular-economy implementation and that open innovation provides complementary external knowledge.

This differentiation matters theoretically. Exploratory innovation involves greater novelty, uncertainty, and long-horizon learning; exploitative innovation emphasizes refinement and incremental improvement. Product innovation changes market offerings, while process innovation targets production and operational systems. Consequently, the

same antecedent may have different effects across innovation forms. A digital platform that improves production analytics may strongly support process eco-efficiency but have weaker effects on radical green product innovation unless combined with external knowledge and R&D capability. Review models that aggregate all green innovation into one node may therefore conceal meaningful causal heterogeneity.

Thematic Synthesis III: Institutional and Financial Conditions

The third stream concerns institutions and finance. Environmental regulation appears among the most frequent terms, while Porter and van der Linde (1995) is the most locally cited reference. This indicates persistent interest in whether appropriately designed regulation stimulates innovation rather than merely increasing compliance costs. Contemporary studies extend this question by examining subsidies, green finance, policy uncertainty, marketization, and competitive conditions. Cai *et al*. (2025) show that the digital economy and marketization jointly influence regional green innovation in China. Liu *et al*. (2025) distinguish the effects of green subsidies and effluent charges. Wang *et al*. (2024) identify financing constraints as a mechanism linking digital transformation with green technology innovation.

Together, these studies imply that digital–green transformation is embedded in an institutional-financial system. Firms may possess digital capabilities and environmental aspirations but remain unable to implement green innovation when financing is constrained, incentives are misaligned, or regulatory signals are unstable. Conversely, supportive green finance and credible environmental policy can increase the expected returns to innovation and lower resource barriers. Future research should therefore test moderated mediation and multi-level models linking firm capabilities to regional financial development, policy stringency, and market institutions.

Thematic Synthesis IV: Capability and Knowledge Perspectives

A fourth stream emphasizes organizational capability. The local citation prominence of Barney (1991), together with keywords such as management, R&D, technology, and performance, indicates that resource-based and capability explanations remain central. Green innovation requires more than access to technology: firms must acquire, assimilate, recombine, and deploy environmental and digital knowledge. This is consistent with studies connecting managerial capacity, absorptive capacity, open innovation, green intellectual capital, and knowledge-management processes to heterogeneous innovation outcomes. Hao *et al*. (2024), for example, examine managerial capacity as a driver of different forms of green innovation, while Perotti *et al*. (2025) emphasize stakeholder engagement and open innovation as mechanisms for acquiring resources and knowledge supporting circular transition.

A capability perspective helps integrate the field because it explains why identical technologies or policy incentives can generate different outcomes across firms. Digital capability improves sensing and data processing; absorptive capacity enables external knowledge assimilation; green human and structural capital embed environmental expertise; and dynamic capabilities support reconfiguration. Green innovation then becomes the observable transformation of these capabilities into new products, processes, and practices. This logic also suggests that green performance should be modeled as a downstream consequence rather than as an automatic synonym for green innovation.

Thematic Synthesis V: from Green Innovation to Green Performance

The fifth stream concerns value realization. “Performance” is the second most frequent term and the second most central co-word node, but performance is measured inconsistently across studies. Some research uses green innovation performance or patent indicators; others examine environmental performance, governance performance, productivity, financial performance, or composite sustainability outcomes. This creates a conceptual problem: an increase in green patents is an innovation output, not necessarily evidence of lower emissions, energy consumption, waste, or ecological impact. Similarly, improved financial performance does not establish environmental improvement.

A stronger research design should separate at least three stages: green innovation output, operational environmental outcome, and organizational/economic value. Green product/process innovation may first alter technologies and routines; these changes may reduce resource intensity, emissions, or waste; and environmental improvements may subsequently influence cost, legitimacy, market position, risk, and financial performance (Nguyen & Nguyen, 2026). Such sequencing reduces construct overlap and enables tests of competing mechanisms. Objective indicators—energy

intensity, carbon intensity, waste reduction, water use, verified emissions, or lifecycle impacts—should complement perceptual survey measures wherever feasible (Al-Madah, 2026).

An Integrative Digital–Green Transformation Framework

Based on the bibliometric structure and thematic synthesis, this review proposes an integrative input–capability–innovation–performance framework **(Table 6)**. The framework is not a direct output of Biblioshiny; it is a theory-oriented synthesis derived from recurring relationships in the corpus. Inputs comprise digital technologies and infrastructure, environmental regulation, green finance, market competition, stakeholder pressure, and managerial commitment. Organizational conversion capabilities include digital capability, absorptive capacity, green knowledge resources, organizational learning, data analytics, and dynamic reconfiguration. These capabilities shape distinct forms of green innovation—product, process, exploratory, exploitative, business-model, and governance innovation. Green innovation then affects objective environmental outcomes and broader organizational performance. Institutional quality, technological turbulence, firm size, ownership, industry pollution intensity, and national development conditions can moderate these paths (Anh *et al*., 2025).

Table 6. Integrative framework for digital–green transformation research.

Stage	Core constructs	Representative research question
Inputs	Digital transformation; regulation; green finance; marketization; stakeholder pressure	Which technological and institutional inputs trigger environmental transformation?
Conversion capabilities	Digital capability; absorptive capacity; learning; green knowledge; managerial capacity	How do firms convert digital and environmental resources into innovation?
Green innovation	Product; process; exploratory; exploitative; business-model; governance innovation	Which innovation form carries the effect and under what conditions?
Environmental outcomes	Energy/resource efficiency; emissions; waste; circularity	Does innovation generate measurable environmental improvement?
Organizational value	Productivity; competitiveness; resilience; financial and green performance	When does environmental improvement translate into organizational value?
Boundary conditions	Policy; finance; turbulence; ownership; industry; country institutions	Why do identical inputs produce heterogeneous outcomes?

Research Agenda

The bibliometric evidence points to six priorities, which are summarized in **Table 7**. First, geographic diversification is essential. With 73.6% of corresponding-author publications from China, replication across Southeast Asia, South Asia, Africa, Latin America, Europe, and North America is required before strong universal claims can be made. Cross-country studies should model institutional differences rather than add country dummies. Second, longitudinal and quasi-experimental designs should replace excessive reliance on cross-sectional association. Policy shocks, staggered digital infrastructure rollouts, environmental-regulation changes, and panel data provide opportunities to strengthen causal identification.

Third, construct precision must improve. Researchers should distinguish digital transformation from digital capability, green digital transformation from generic digitalization, green innovation from green innovation performance, and green performance from general firm performance. Fourth, future studies should disaggregate green innovation types. Product, process, exploratory, exploitative, business-model, and governance innovation are unlikely to have identical antecedents or consequences. Fifth, objective sustainability indicators should be integrated with survey and patent measures. Finally, multi-level and configurational approaches are needed. Digital–green outcomes may result from combinations of technology, capabilities, finance, regulation, and stakeholder pressure rather than from one dominant linear predictor.

Table 7. Future research agenda.

Gap identified	Recommended design	Expected contribution
Geographic concentration	Cross-country matched samples; multi-level institutional models	Test boundary conditions and external validity
Direct-effect dominance	Longitudinal mediation; panel models; natural experiments	Identify temporal and causal mechanisms
Construct overlap	Explicit construct definitions and discriminant validation	Reduce conceptual ambiguity
Aggregated green innovation	Model product/process and exploratory/exploitative forms separately	Reveal heterogeneous pathways
Perceptual sustainability outcomes	Combine surveys with emissions, energy, waste, patent, and lifecycle data	Strengthen criterion validity
Linear single-path models	fsQCA, latent classes, network models, moderated mediation	Capture equifinality and contingency
Weak digital environmental accounting	Measure energy/material footprint of digital systems alongside benefits	Avoid one-sided claims about digital sustainability

Methodological Patterns and Implications for Evidence Quality

A further issue emerging from the corpus is methodological concentration. Many highly visible studies exploit Chinese listed-firm or provincial panel data, green patent counts, digital-transformation text indices, policy variables, and econometric mediation or moderation models. These designs offer important advantages: large samples, repeated observations, and opportunities to address endogeneity through fixed effects, instrumental variables, spatial models, or policy shocks. At the same time, reliance on archival proxies can narrow the meaning of both digital transformation and green innovation. Text-based digitalization indices may capture managerial disclosure as well as actual capability deployment, while patent counts measure codified inventive output rather than implementation, diffusion, or realized environmental benefit. The field would benefit from triangulation that combines archival indicators with plant-level operational data, digital-system adoption measures, interviews, and validated organizational scales.

Survey-based research faces the complementary challenge of common method variance and perceptual inflation. When the same respondent rates digital capability, green innovation, and green performance in a single questionnaire, correlations may partly reflect shared method, social desirability, or a general positive evaluation of the firm. Stronger designs can separate measurement sources and times, collect innovation information from R&D or operations managers, obtain environmental indicators from sustainability systems, and use financial or market outcomes from archival sources. Multi-informant designs are especially valuable for green digital transformation because digital infrastructure, environmental management, and strategic performance often reside in different organizational functions.

The corpus also demonstrates increasing use of mediation, moderation, spatial analysis, and threshold models. These methods are useful only when aligned with theory. A statistically significant mediator should represent a temporally plausible mechanism rather than a variable inserted between two correlated constructs. Likewise, moderation by policy uncertainty, environmental regulation, market competition, or managerial cognition should be grounded in a clear boundary-condition argument. Future bibliometric and systematic reviews could code methods explicitly—panel versus cross-sectional data, causal identification strategy, objective versus perceptual outcomes, unit of analysis, and country setting—to determine whether substantive conclusions are robust across research designs.

Sustainability Integrity and the Digital Rebound Problem

A critical agenda concerns the environmental integrity of digital transformation itself. Much of the literature examines whether digitalization stimulates green innovation, but a complete sustainability assessment must also consider the energy, hardware, data-center, and material footprint associated with digital systems. A firm could improve production efficiency through advanced analytics while simultaneously increasing electricity use, computing demand, device turnover, or upstream resource consumption. Without accounting for these countervailing effects, "digital green transformation" may be inferred from partial indicators. Future research should therefore distinguish gross

environmental benefits from net environmental benefits and, where possible, incorporate lifecycle or scope-based accounting.

This issue is especially important as artificial intelligence, cloud computing, industrial internet platforms, and data-intensive monitoring become embedded in sustainability strategies. The appropriate research question is not simply whether a digital technology is associated with green innovation, but whether the innovation creates environmental gains that exceed the direct and indirect footprint of the digital infrastructure used to generate it. Such analysis would connect management research more closely with responsible digitalization and prevent sustainability claims from becoming technology-centric. It would also open a new interface between green innovation research and emerging work on efficient computing, digital sobriety, circular electronics, and responsible AI.

Toward Stronger Cumulative Theory

The field can also improve cumulative theory by specifying competing explanations. Resource-based and dynamic-capability perspectives predict that heterogeneous internal capabilities determine value creation from digital and green resources. Institutional and Porter-hypothesis perspectives emphasize regulatory incentives and external legitimacy. Knowledge-based and absorptive-capacity explanations focus on acquisition and recombination of environmental knowledge. Stakeholder perspectives highlight demands from customers, investors, communities, and supply-chain partners. Rather than adding several theories to the same model without integration, future studies should identify what each theory uniquely predicts and design tests that discriminate among explanations. For example, if regulation improves green innovation primarily through compliance pressure, effects should vary with enforcement exposure; if the mechanism is capability building, effects should depend more strongly on learning and absorptive capacity.

A useful cumulative structure is to separate antecedent theories, conversion theories, and outcome theories. Institutional and stakeholder perspectives explain why firms face pressure or incentives to act. Resource, knowledge, and dynamic-capability perspectives explain how firms convert resources and information into green innovation (Thanh *et al*., 2026). Innovation and performance perspectives explain how those changes affect environmental and economic outcomes. This layered approach reduces theoretical redundancy and aligns naturally with the input–capability–innovation–performance framework developed in this review. It also allows future meta-analytic work to compare effect sizes across theoretically equivalent pathways rather than pooling relationships that use similar labels but represent different mechanisms.

Theoretical Implications

The review has three theoretical implications. First, it repositions digital transformation as an enabling infrastructure rather than a sufficient cause of green performance. This avoids digital determinism and directs attention to conversion capabilities. Second, it identifies green innovation as the central mechanism linking technological, organizational, financial, and institutional antecedents to sustainability outcomes. The high frequency and network centrality of green innovation support this mediating role at the field level, while representative empirical studies show multiple mechanisms through which digitalization and policy affect innovation. Third, the review integrates institutional and capability perspectives. Regulation and finance influence incentives and resource availability, whereas organizational capabilities determine whether firms can exploit those opportunities. The resulting framework is therefore explicitly contingent: green performance depends on alignment among external pressures, internal capabilities, innovation choices, and outcome measurement.

Managerial and Policy Implications

For managers, the central implication is that digital investment should be governed through explicit environmental objectives (Al-Madah, 2025). Firms should connect analytics, automation, AI, platforms, and digital monitoring to defined resource, emissions, waste, or circularity targets; build absorptive and learning capabilities; and evaluate whether digital projects generate green product/process changes rather than only efficiency gains. Green innovation portfolios should also be differentiated. Incremental process improvements may require different resources and incentives from exploratory green technologies or circular business-model innovation.

For policymakers, the literature suggests that regulation, subsidies, market institutions, and green finance can shape innovation incentives, but instrument design matters. The different responses of exploratory and exploitative innovation to fiscal instruments reported by Liu *et al*. (2025) illustrate why a single undifferentiated "green support" policy may be insufficient. Policy evaluation should therefore track not only the number of green patents or projects but also additionality, diffusion, environmental outcomes, and heterogeneity across firm size, ownership, and industry.

Conclusion

This review maps 341 Web of Science articles at the intersection of green digital transformation, green innovation, and green performance. The evidence shows a young, citation-intensive, and rapidly expanding domain distributed across technology forecasting, strategy, finance, innovation, and sustainability journals. Green innovation is the dominant conceptual hub, while performance, environmental regulation, digital transformation, finance, circular economy, management, and sustainability form interconnected streams. The field's intellectual base combines the Porter hypothesis, eco-innovation, resource-based reasoning, and contemporary digital-transformation research.

The synthesis indicates that digital transformation should not be equated with environmental improvement. Its value lies in enabling information processing, coordination, monitoring, and resource reconfiguration; organizational capabilities convert these affordances into green innovation; and green innovation must then produce verifiable environmental outcomes before claims of green performance are warranted. Institutional and financial conditions shape each stage. This input–capability–innovation–performance architecture provides a clearer basis for cumulative theory building than models that connect generic digitalization directly to broad performance constructs.

The review also identifies important limitations in the current knowledge base: strong geographic concentration in China, construct overlap, heterogeneous outcome definitions, limited separation of green innovation forms, and insufficient use of objective environmental measures. Future research should employ longitudinal, cross-country, multi-level, and configurational designs and should account for the environmental footprint of digital technologies themselves. By connecting bibliometric structure with theory-oriented synthesis, the review provides a roadmap for research that is more precise about when, how, and under what conditions digital transformation contributes to genuinely greener organizational outcomes.

Limitations and Directions for Future Research

This review has limitations. First, the dataset is based on Web of Science, and a deliberately restricted set of indexes, publishers, Business/Management categories, and SDG 12, so relevant studies in Scopus-only journals or adjacent disciplines may be omitted. Second, the search expression prioritizes three broad phrases and may miss studies using terms such as digital sustainability, eco-innovation, environmental innovation, Industry 4.0 sustainability, or digital circularity without the selected phrases. Third, bibliometric indicators are sensitive to database indexing, keyword standardization, and citation age. Fourth, the 2022–2026 eligibility filter conflicts with two 2027-indexed records in the exported metadata; this should be verified before final submission. Finally, bibliometric co-occurrence and co-citation identify intellectual proximity, not causality. The integrative framework proposed here is therefore a synthesis for future testing rather than a causal result of the mapping procedure.

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