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Systematic Review

Digital Transformation and Circular Economy Adoption in Digital Business: A Systematic Review of Enabling Mechanisms, Boundary Conditions, and Value Outcomes

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Abstract

Digital transformation can help firms put circular-economy practices into operation. Existing studies often discuss technical tools and implementation practices separately. Few studies explain the organizational logic that connects the two. This systematic review identifies 146 peer-reviewed English-language journal articles published from January 2015 to June 2026. The review follows PRISMA 2020. It examines how digital technologies support circular-economy adoption at the firm and organizational levels. Industry and supply-chain levels are also included. The evidence points to three core mechanisms. The first is information transparency. The second is resource-efficiency optimization. The third is circular business-model innovation. Their effects depend on internal green and digital capabilities. Supply-chain coordination and external institutional pressures also change how these mechanisms work. Environmental outcomes receive the most consistent empirical support. Operational and social outcomes depend more strongly on context and innovation and economic outcomes are also context-dependent. This review integrates dynamic capabilities theory with the natural-resource-based view and institutional theory to distinguish internal capability development from external constraints. The resulting framework links mechanisms with boundary conditions and outcomes while identifying priorities for longitudinal research, comparative research and improved outcome measurement.

Keywords: digital transformation; digital platforms; circular economy adoption; digital governance; sustainable value; public value

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1. Introduction

Digital transformation and circular-economy adoption have become connected strategic challenges because firms must address resource constraints and environmental expectations while competing in data-intensive markets. Product life-cycle responsibilities also continue to change as circular-economy strategies retain product and component value through reuse and repair. Remanufacturing and recycling extend material use value [1–3] while circular business models support the same goal through more visible material flows. Digital technologies can support predictive maintenance and coordinate return channels [4] while also providing information for circular decisions. Recent firm-level evidence links digital capability with circular-economy implementation and resource orchestration [5], but technology ownership alone does not indicate that a circular transition has occurred. Firms must turn data and connectivity into stable organizational routines and automation

and digital-platform resources must also enter daily operations. These routines change how products are designed and used and they also change how products are recovered and recirculated.

This translation process has practical importance and digital investment may improve efficiency in one part of the firm. It does not always create broader circular value and some firms collect data but do not redesign operations. Some firms improve one process but leave material loops unchanged and other firms adopt a platform but do not build governance rules for inter-firm coordination. Research on digital transformation therefore gives attention to organizational change and business-model renewal [6,7], and capability development and performance outcomes are also central concerns. Circular-economy research focuses on closed-loop supply chains and product stewardship [1,2] and also examines resource recovery and circular value creation. Empirical work offers a further warning and efficiency gains supported by Industry 4.0 may remain local [8]. They do not always improve overall sustainability performance and if managers and policy makers assume that the two agendas fit together automatically then investment may target visibility or productivity alone. Circular practices may still remain fragmented. They may also remain weakly coordinated and difficult to scale.

Existing research provides an important foundation. Prior reviews map links between digital technologies and circular-economy strategies and identify major Industry 4.0 applications [9–11] while also proposing agendas for the digital–circular intersection. Other studies explain the organizational character of digital transformation [6,7] and the role of digital capabilities in circular-economy implementation [4,5]. This work shows that the field extends beyond isolated technical applications. Yet, empirical evidence remains dispersed across management, operations and environmental science. Engineering studies add further evidence and supply-chain studies also use different units of analysis. They also use different mechanisms and outcome measures.

At the study level, the evidence suggests several technology-enabled paths. Blockchain supports traceability and information verification in circular supply chains [12,13]. Internet of Things applications improve data visibility and circular supply-chain integration [14,15]. Big-data analytics and digital twins support process monitoring and resource allocation [16–21]. Related Industry 4.0 configurations also support green purchasing, remanufacturing and circular operating performance [16–21]. Digital platforms can coordinate partners and return flows [22,23], while ecosystem arrangements support circular value propositions [24,25]. The issue is therefore not whether the two research streams overlap. The central problem is how heterogeneous evidence explains the organizational process through which digital resources become circular action.

The first research gap concerns mechanisms because many studies list technologies or circular practices without distinguishing the organizational path that links them. These paths include information transparency, resource-efficiency optimization and business-model innovation while explaining why the same tool supports circular adoption in one setting but remains a stand-alone project elsewhere [4,22]. The second gap concerns boundary conditions because evidence from SMEs and emerging markets shows that firm size and technological readiness can alter implementation [26–33]. Absorptive capacity and managerial support also matter while institutional pressure and coordination arrangements create further variation that existing studies rarely connect to the mechanisms they enable or constrain.

The third research gap concerns outcomes because environmental benefits are reported most often while operational and innovation outcomes rely on different measures. Economic and social outcomes also use different time horizons and contextual assumptions, while studies report both gains in resource efficiency [16–21] and implementation barriers

with rebound risks [8,11,34–37]. Without a framework that connects mechanisms with conditions and outcomes, it remains difficult to determine which forms of value receive consistent support and which findings remain mixed. Evidence is still too limited in some areas to support general conclusions.

To address these gaps, this review combines three complementary theoretical perspectives that explain different parts of the digital–circular relationship. The natural-resource-based view identifies internal green capabilities and product-stewardship routines [38], while dynamic capabilities theory explains how firms sense opportunities and seize them through investment and coordination [39,40]. Dynamic capabilities theory also explains how firms reconfigure routines and relationships while institutional theory addresses coercive and mimetic pressures as well as normative pressures [41]. Together the three perspectives distinguish internal capability bases from external pressure and locate the conditions that shape the conversion of digital resources into circular value.

This review addresses three research questions that move from organizational mechanisms to boundary conditions and reported outcomes. RQ1 examines how digital transformation supports circular-economy adoption while RQ2 considers the firm-level and supply-chain-level conditions that shape these mechanisms. RQ2 also considers institutional conditions while RQ3 examines environmental and operational outcomes alongside social and innovation outcomes. Economic outcomes and areas of incomplete evidence are also included so the review can organize the 146-study corpus around mechanisms and boundary conditions. The analysis also distinguishes internal green capabilities from external institutional pressures while identifying a need for stronger causal and longitudinal research. Comparative and ecosystem-level work remains important because data governance and digital platforms shape circular value creation while inter-firm coordination and verifiable information determine whether that value can persist across product life cycles [23,24,42].

2. Theoretical Background

2.1. Dynamic Capabilities Theory: The Perspective of Core Mechanism Paths

Dynamic capabilities theory explains how firms renew competences when the environment changes. Firms sense opportunities and risks. They seize opportunities through investment and coordinated decisions [39,40]. They also reconfigure assets and routines. Relationships may be reconfigured as well. In this review these processes provide a mechanism lens. Digital data and connectivity can support sensing. Operational deployment can support seizing. Changes in routines and supply-chain relationships can support reconfiguration. Changes in business models can do the same.

Dynamic capabilities theory fits this review because digital transformation and circular-economy adoption both require continuing organizational renewal rather than one-time technology purchases. Digital tools create potential value only after firms redesign information systems and resource-allocation routines [6,7] while adjusting learning processes and organizational structures. Durable circular-economy adoption also requires coordinated changes in product design and production processes [2,3], together with changes in supply-chain relationships and business models. Isolated operating decisions are therefore not sufficient.

Prior research shows that accumulated digital capabilities can support circular-economy adoption [4,5,9]. They can improve resource allocation and market sensing. They can also improve operational adaptation. Dynamic capabilities therefore provide a useful basis for studying how digital investment becomes circular practice over time. In this review sensing organizes the analysis of information acquisition. Seizing organizes the

analysis of operational implementation. Reconfiguring organizes the analysis of internal organizational change.

2.2. The Natural-Resource-Based View of the Firm: The Perspective of Strategic Choice Motivation

The natural-resource-based view adds a strategic-choice perspective to the mechanism analysis. It explains the strategic value of internal green capabilities. The view builds on the resource-based view. It emphasizes pollution prevention and product stewardship [38]. Sustainable development is also treated as a capability domain. These capabilities can help firms build advantage while reducing environmental burdens. In the present framework NRBV is not a measure of regulatory pressure. It concerns resources and routines developed inside the firm. It also concerns learning and green strategic commitment.

2.3. Institutional Theory: The Perspective of External Pressure and Contextual Variation

Institutional theory provides the third perspective because circular-economy adoption is rarely shaped by internal capabilities alone. DiMaggio and Powell [41] argue that organizations become more similar under coercive and mimetic pressure while normative pressure can produce the same tendency. In the digital–circular setting, coercive pressure includes environmental regulation and carbon reporting rules while product passport requirements and supply-chain compliance demands belong to the same category. Mimetic pressure appears under uncertainty as firms copy digitally enabled circular practices used by competitors and industry leaders. Platform partners may become models for imitation while normative pressure comes from professional standards and certification bodies. Industry associations and ESG expectations also matter because stakeholder demands for transparency and responsible resource use create further pressure.

This perspective is particularly relevant because digital transformation produces different effects across countries and industries while a firm's supply-chain position can create further variation. The same technology may support circular-economy implementation in one setting but have a weaker effect elsewhere because regulatory enforcement and data-sharing rules differ. Infrastructure readiness and customer expectations add further variation while institutional theory helps explain how these external pressures shape adoption and legitimacy. Dynamic capabilities theory explains how firms sense and seize circular opportunities while the natural-resource-based view explains why environmental and circular objectives can have strategic value. Together these perspectives clarify how external context shapes implementation and the potential scale of circular practices.

3. Methodology

3.1. Review Method

This study uses a systematic literature review to examine the relationship between digital transformation and circular-economy adoption at the firm level. The evidence covers management and operations management. Environmental science and engineering are also included. Supply-chain research is part of the evidence base. A systematic review fits this topic because it makes the search and screening process transparent [43,44]. It also makes eligibility decisions and synthesis procedures visible. This supports later replication.

This review follows PRISMA 2020 as the reporting framework [45]. Records of the search and screening process are retained in the Supplementary Materials. Full-text eligibility decisions and study-level coding audits are also retained. Wenbin Su conducted the screening under prespecified eligibility criteria. He also completed the full-text eligibility assessment and study-level coding. All decisions followed documented rules. Ambiguous records were checked again against the complete report. The documented rules were also reviewed. Woojin Yoon reviewed the eligibility framework and difficult cases. He also

reviewed the final synthesis. The records were not independently screened in duplicate. For this reason no inter-rater agreement statistic is reported. The included studies differ substantially in design and setting. Their constructs and outcome measures also differ. The review therefore uses thematic synthesis rather than meta-analysis [46,47].

The corpus is methodologically heterogeneous. For this reason a design-sensitive quality appraisal was added during revision. Primary empirical studies were assessed with the applicable MMAT 2018 criteria. Systematic reviews and research syntheses were assessed with the JBI checklist. Conceptual and nonempirical studies were not given an empirical quality score. The appraisal did not retrospectively exclude any study. It also did not change the 146-study analytic corpus. No overall numerical quality score was calculated. All 146 studies were routed according to their full-text design. Each study then entered the applicable appraisal pathway.

The design-sensitive appraisal covered 119 empirical reports with MMAT. Nine systematic reviews or research syntheses were assessed with JBI. The remaining 18 conceptual or nonempirical studies were not subjected to empirical-method appraisal. Most empirical reports clearly stated their research questions and data sources. Most also reported their analytical procedures. Information about sampling representativeness was often unclear. Non-response-bias information was also often missing. Several mixed-method reports provided too little information about integration. Their treatment of divergent findings was also difficult to judge. The synthesis therefore treats apparently uniform positive patterns with caution. These patterns are interpreted as context-dependent. They are not treated as evidence of universal effects.

3.2. Search Rules

The search covered January 2015 to June 2026. It was conducted on 13 June 2026. Web of Science Core Collection and Scopus were selected. Together they provide broad coverage of management and operations. They also cover supply-chain and environmental research. Digital-business research is well represented. Both databases provide structured bibliographic fields. These fields support duplicate detection and transparent screening. Searches used the recorded title and abstract fields. Keyword fields were also used. The time window captures the period when digital-economy and circular-economy agendas became jointly important for firms and supply chains.

A common Boolean logic was used to identify research at the intersection of digital transformation and the circular economy while requiring an organizational setting. Database information and recorded field scope are documented in the Supplementary Materials together with search dates and eligibility limits. The recorded database yields are retained and reconstructed platform-specific search strings are clearly marked as non-verbatim historical reconstructions.

(“digital transformation” OR “digitalization” OR “digitalisation” OR “Industry 4.0” OR “digital technology” OR “digital technologies”) AND (“circular economy” OR “circularity” OR “green strategy” OR “sustainable innovation” OR “green innovation”) AND (“firm” OR “enterprise” OR “organization” OR “organisation” OR “company” OR “manufacturing”)

Backward searching of reference lists was used as a supplementary identification procedure. Forward citation searching was also used for relevant reviews and core studies. Records found through these procedures were assessed with the same eligibility criteria.

3.3. Inclusion and Exclusion Criteria

Eligible records were peer-reviewed English-language journal articles published from January 2015 to June 2026 and each article had to address a substantive relationship

between digital transformation and circular-economy adoption. Digitalization and Industry 4.0 studies were also eligible and studies of a specific digital technology were included when they addressed circular practices or outcomes. The study also needed relevance to firms or organizations and industry and supply-chain settings were eligible. Business-ecosystem studies were also eligible and studies were excluded when the digital–circular connection was not substantive. They were also excluded when the unit of analysis lacked organizational relevance and publication types outside the stated criteria were removed.

Duplicate records were identified with DOI and title information, and author and publication-year information supported the check. Duplicate metadata entries were consolidated during final report-identity reconciliation and this occurred before the number of unique reports sought for retrieval was reported. Retrievability was treated as a procedural screening status and it was not treated as a substantive eligibility criterion. Reports without a confirmed usable full text at the original eligibility-assessment cut-off were recorded separately and they did not enter full-text eligibility assessment at that stage.

Table 1 presents the substantive screening standards used in this review. It shows which types of articles were retained for analysis. It also shows which types were excluded from the final sample. Retrieval status is reported separately in the PRISMA audit.

Table 1. Inclusion and exclusion criteria. Source: Prepared by the authors.

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal article	Conference papers, book chapters, editorials
English-language publication	Non-English publications
Published between January 2015 and June 2026	Publications outside the time window
Addresses both digital transformation/digital technologies and circular economy/circular practices	Studies addressing only one topic without a substantive digital–circular connection
Firm-, organization-, industry-, or supply-chain-level implication	Macro-level policy studies without firm-level implication; purely technical studies without management relevance

3.4. Screening Process

As shown in Figure 1, the screening process included identification and record-level screening. It also included full-text retrieval and eligibility assessment. Final inclusion was the last step. Web of Science Core Collection returned 5321 records. Scopus returned 6024 records. After duplicate removal 7053 unique records entered title-and-abstract screening.

The broad title-and-abstract stage excluded 5851 records and these records clearly failed one or more prespecified criteria. A focused eligibility and identity check was then conducted at the record level and this step excluded another 1036 records. A total of 166 unique reports remained for full-text retrieval and the reconciliation process identified one additional duplicate report. It was removed during metadata and identity review and the record-level audit records the applicable criterion for each exclusion. Ambiguous records were retained for full-text assessment.

Among the 166 unique reports sought for retrieval, seven lacked a confirmed usable full text at the original eligibility-assessment cut-off. The other 159 reports entered full-text assessment. Thirteen were excluded for eligibility reasons. The final analytic corpus therefore contained 146 studies. During revision the full texts of the seven previously unavailable reports became accessible. By that time the 146-study coding matrix was already complete. The descriptive analysis and thematic synthesis were also complete. The revised manuscript therefore retains the fixed 146-study analytic corpus. The seven reports retrieved during revision are documented separately in the Supplementary Materials. They

were not used to generate Tables 2 and 3. They were also not used to generate the thematic findings reported here. A future update should incorporate these reports formally.

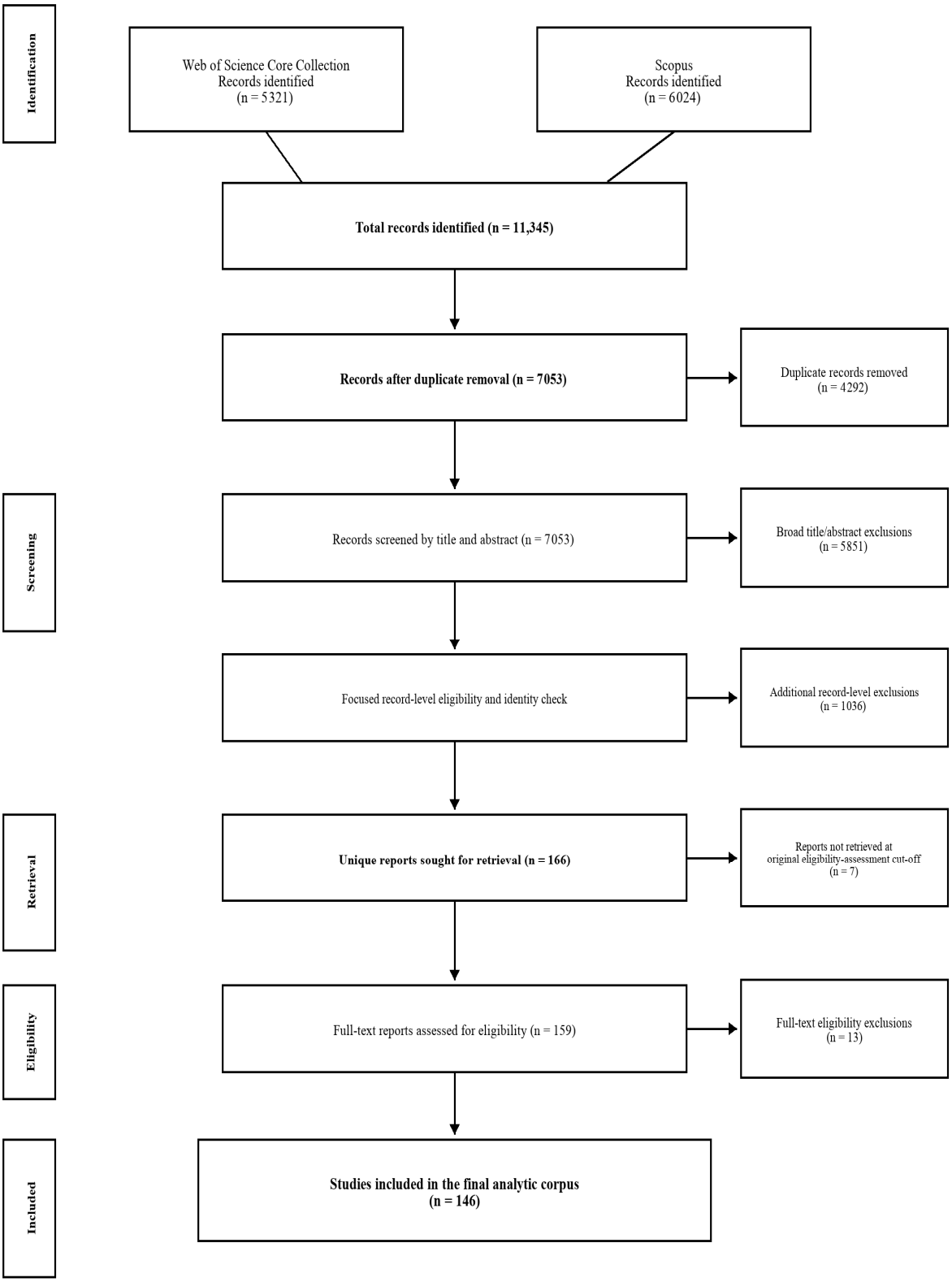


Figure 1. PRISMA flow diagram of the systematic literature review process. Source: Authors' PRISMA screening audit. The diagram reflects status at the original eligibility-assessment cut-off; Supplementary Table S3 documents the revision-stage retrieval update. The final thematic synthesis includes the frozen 146-study analytic corpus.

Table 2. Descriptive profile of the frozen 146-study analytic corpus.

Section	Category	*n*	%
Publication year	2015–2019	1	0.7
Publication year	2020–2022	23	15.8
Publication year	2023–2026	122	83.6
Study design	Quantitative	88	60.3
Study design	Qualitative/case study	15	10.3
Study design	Conceptual/review	30	20.5
Study design	Mixed methods	12	8.2
Study design	Other	1	0.7
Geographic context	China	14	9.6
Geographic context	Asia excluding China	37	25.3
Geographic context	Europe	5	3.4
Geographic context	Multi-country/global	29	19.9
Geographic context	Other/not specified	61	41.8
Industry/context	Manufacturing	55	37.7
Industry/context	Logistics/supply chain	48	32.9
Industry/context	Food/agri-food	9	6.2
Industry/context	Other/cross-sector	34	23.3
Digital technology	Industry 4.0	68	46.6
Digital technology	Big data/analytics	36	24.7
Digital technology	Artificial intelligence	21	14.4
Digital technology	Digital-transformation capability	22	15.1
Digital technology	Blockchain	33	22.6
Digital technology	IoT	29	19.9
Mechanism	Information transparency	72	49.3
Mechanism	Resource-efficiency optimization	78	53.4
Mechanism	Business-model innovation	29	19.9
Boundary condition	Firm-level	41	28.1
Boundary condition	Supply-chain level	28	19.2
Boundary condition	Institutional	17	11.6
Value outcome	Environmental	109	74.7
Value outcome	Operational	57	39.0
Value outcome	Social	47	32.2
Value outcome	Innovation	46	31.5
Value outcome	Economic	69	47.3

Note. Percentages are calculated as $n/146 \times 100$. Publication year, study design, geographic context, and industry/context are mutually exclusive. Digital technology, mechanism, boundary condition, and value outcome are multi-coded; their category percentages therefore do not sum to 100%. Source: Authors' calculations from the frozen 146-study coding matrix in Supplementary Table S2.

Table 3. Cross-analytical matrix linking digital technologies, organizational capabilities, and external institutional pressures in the frozen 146-study analytic corpus.

Digital Technology	Sensing/Information	Seizing/Operations	Reconfiguring/ Business Model	External Institutional Conditions	Representative Studies
Blockchain and distributed ledgers	Traceability, verifiable records, and material-flow visibility	Verification, trusted exchange, and reverse-logistics coordination	Data-governance and partner-role redesign	Compliance, standards, privacy, and trust requirements	Joshi et al. [12]; Mankata et al. [48]; Kayikci et al. [13]
IoT, sensors, and digital twins	Real-time product, asset, and resource monitoring	Predictive maintenance, process control, and recovery decisions	Closed-loop operations and lifecycle-data routines	Infrastructure, interoperability, and industry requirements	Juma et al. [14]; Oluleye et al. [49]; Findik et al. [26]

Table 3. *Cont.*

Digital Technology	Sensing/Information	Seizing/Operations	Reconfiguring/ Business Model	External Institutional Conditions	Representative Studies
Big-data analytics and AI	Opportunity recognition from integrated operational data	Prediction, allocation, and circular decision support	Analytics-enabled process and capability renewal	Data access, skills, accountability, and regulatory expectations	Qurtubi et al. [29]; Juma et al. [14]; Mukherjee et al. [27]
Digital platforms and ecosystems	Visibility across customers, suppliers, and recovery partners	Matching, coordination, and circular-service deployment	Platform rules, circular value propositions, and ecosystem governance	Network legitimacy, standards, and stakeholder expectations	Lim et al. [23]; Bui et al. [25]; Wiegand and Wynn [50]
Industry 4.0 configurations	Connected data, automation, and resource-flow insight	Production and supply-chain optimization	Routines, partner relationships, and circular-business-model renewal	Policy support, technology readiness, and industry norms	Wang et al. [33]; Mai et al. [51]; Sahoo et al. [52]

Note. This is an interpretive matrix supported by the representative studies in the final column; complete study-level coding, source traceability, and available evidence locators are provided in Supplementary Table S2. Dynamic capabilities describe organizational processes, NRBV describes internal green strategic capabilities, and institutional theory describes external coercive, mimetic, and normative pressures. Source: Authors' synthesis from the frozen 146-study coding matrix.

The complete list of the 146 included studies is provided in Supplementary Table S1. The study-level coding matrix is provided in Supplementary Table S2. Supplementary Table S3 records the seven reports that became available during revision. These reports were not incorporated into the fixed analytic corpus.

3.5. Data Extraction and Thematic Coding

A structured extraction template recorded bibliographic information and research design together with research context and digital technology. Circular-economy practices and mechanisms were coded alongside boundary conditions and value outcomes while theoretical lens and evidence direction were also recorded. Evidence locators were retained for traceability and deductive categories came from the integrated framework while recurring patterns were refined through inductive coding when clarification was needed. Supplementary Table S2 retains the study-level audit trail and Tables 2 and 3 are generated only from the fixed 146-study coding matrix.

4. Results

4.1. Overview of the Literature

This section profiles the 146 studies included in the thematic synthesis. The profile covers publication year and research design. Geographic and industry context are also described. Digital technology and mechanism are included. Boundary conditions and value outcomes are included as well. The profile shows where the evidence is concentrated. It also identifies areas that require cautious interpretation.

Table 2 reports the descriptive profile calculated directly from the fixed 146-study coding matrix. The underlying matrix appears in Supplementary Table S2. All frequencies and percentages use N = 146 as the denominator. The table separates mutually exclusive descriptive categories from thematic categories that allow multiple coding.

The evidence base is recent and heterogeneous with quantitative designs accounting for the largest share while manufacturing and supply-chain settings are also prominent. Multi-country studies remain substantial and other or unspecified geographic contexts are common, while information transparency and resource-efficiency optimization are the most frequently coded pathways. Business-model innovation appears less often while

environmental outcomes are reported most frequently and the multi-coded outcome categories require context-sensitive interpretation. Operational and social outcomes require this caution, while innovation and economic outcomes should be interpreted in the same way [12,16,23,26].

4.2. Mechanisms Between Digital Transformation and Circular Economy Adoption

The first research question examines the organizational paths through which digital transformation supports circular-economy practices and the reviewed literature indicates more than one channel. Three core mechanisms emerge from the evidence, and these are information transparency and resource-efficiency optimization together with circular business-model innovation [12,16,22]. These mechanisms relate to the three dimensions of dynamic capabilities without forming a mechanical one-to-one match because information transparency supports sensing and resource-efficiency optimization supports seizing. Business-model innovation reflects reconfiguration because firms must redesign routines and partner roles while changing the logic of value capture around circular principles.

4.2.1. Information Transparency Mechanism

The information-transparency mechanism explains how digital technologies increase the visibility of materials and products and also increase the traceability of transactions and circular-system participants. For firms implementing circular-economy practices, this visibility supports product tracking after sale and also supports reverse-logistics monitoring and recycled-material verification. Data coordination across multiple partners becomes easier and traditional manual systems have difficulty managing these activities. Digital technologies therefore provide important infrastructure for reducing information asymmetry. They also strengthen circular coordination [12–15,23].

Blockchain and Internet of Things technologies appear frequently in this stream and blockchain-based distributed ledgers can support product traceability and transaction verification. They can also build trust among partners handling recycled materials and second-hand products. Joshi et al. [12] show this potential in closed-loop electronic-waste supply chains. Kayikci et al. [13] identify blockchain-enabled information transparency as an important condition for circular supply-chain development and studies of the Internet of Things emphasize real-time data collection and use. Juma et al. [14] explain how IoT can help manufacturing firms integrate circular supply chains. Junaid et al. [15] show that stronger supply-chain visibility can support circular-economy practices in Chinese firms and together these studies indicate that digital technologies can reduce information asymmetry. They can also reduce coordination uncertainty and both problems are persistent barriers to circular implementation.

Some studies move beyond the visualization function of technology itself and they define information acquisition capability as a core organizational capability. This distinction is theoretically important, and from a dynamic capabilities perspective, raw data do not automatically become sensing capability. This applies to blockchain and IoT and also applies to digital platforms and big-data systems. Data become sensing capability only when firms have appropriate governance arrangements, and firms also need interpretive routines and data-quality controls. Absorptive capacity is another necessary condition and these elements allow managers to recognize circular opportunities and risks. Sahoo et al. [53] propose that a firm's information acquisition capability strengthens the link between Industry 4.0 technologies and circular outcomes and the finding shows that information transparency is not only about collecting more data. Firms must interpret the data and embed it in decision routines and they must then use it for circular decisions.

Firm size and prior readiness can change the effect of the information-transparency mechanism. Studies of micro and small enterprises support this point. Even when small firms use digital technologies to improve transparency they often face financial constraints. Technical talent can also be limited. Supporting data infrastructure is another common barrier. Findik et al. [26] show that firm size changes the effect of Industry 4.0 on circular-economy implementation in European SMEs. Mukherjee et al. [27] show that external institutional requirements interact with firms' technical levels in India. This interaction shapes blockchain adoption among SMEs. Alam et al. [28] find that institutional constraints and technological readiness affect blockchain adoption in Bangladeshi garment firms. Qurtubi et al. [29] also report clear readiness differences among SMEs in developing countries. These differences affect Industry 4.0 use. They also affect the construction of data systems for a circular economy.

The same unresolved issue appears in research on big-data use and decision optimization. It also appears in work that combines Industry 4.0 with a circular economy. Many scholars call for greater attention to capability thresholds. Implementation conditions also require more research. Anwar et al. [30] provide related empirical evidence and Alsaoudi et al. [10] identify the same issue in their review.

4.2.2. Resource Efficiency Optimization Mechanism

Resource-efficiency optimization is the most frequently coded mechanism. This pattern shows that the current evidence base is strongly oriented toward operating practice. The mechanism has a simple core logic. Digital technologies help firms manage materials and energy more precisely. They also help firms manage production equipment and capacity. This can improve the implementation of circular-economy practices. Real-time monitoring and predictive analytics can reduce waste. Digital twins and automated decision support can improve resource allocation. These tools can also identify opportunities for reuse and repair. Recycling opportunities can be identified as well [16–21,34].

Empirical evidence shows that digital technologies can improve resource-use efficiency in manufacturing and supply chains and digital twins can strengthen production monitoring and process optimization. This creates more favorable conditions for circular practices. Liu et al. [16] report a similar pattern, and AI-enabled reverse-logistics systems are also associated with stronger circular outcomes among Indian SMEs [17]. Prashar and Chaudhuri [18] find that IoT and big-data analytics can strengthen operational capabilities during digital–circular transformation. Sahoo et al. [19] connect big-data analytics capability with circular-economy implementation, and related studies also link Industry 4.0 with green purchasing and remanufacturing [20,21]. Sustainable-development outcomes are also connected with these technologies.

The effect of resource-efficiency optimization is not always positive and some studies show that a higher operating efficiency does not automatically create broad sustainability benefits. Neto et al. [8] provide a representative case and Industry 4.0 technologies promoted cleaner production at the micro level. They also supported small-scale circular transformation and overall sustainable-development performance did not improve at the same time. This result is consistent with the rebound-effect argument and resource use may fall in one production process. The firm may then expand total production and it may also add other resource-consuming activities. The original efficiency benefit can gradually be offset. Jabbour et al. [34] also report complex effects after joint adoption of Industry 4.0 and the circular economy. Cuevas-Pichardo et al. [35] and Matarneh et al. [36] reach a related conclusion, and final outcomes depend heavily on internal capability and implementation conditions.

This mixed evidence gives resource-efficiency optimization a strong empirical base and also leaves room for disagreement. Existing studies show that digital technologies can optimize production processes and they can reduce material loss and support circular operations. Yet, researchers should not equate operating efficiency with a complete circular transition. Neto et al. [11] argue that future research should identify the conditions for strong sustainability outcomes and this question is especially important when Industry 4.0 and the circular economy are combined. Ghaithan et al. [37] also note that outcome measures are not standardized and it is therefore difficult to judge whether higher resource efficiency becomes genuine circular-development performance.

4.2.3. Business Model Innovation Mechanism

The third mechanism is business-model innovation and fewer empirical studies examine this path than the first two mechanisms. It nevertheless has strong theoretical value and the mechanism goes beyond day-to-day operating improvement. It examines how digital transformation can rebuild the logic of value creation, and value delivery and value capture must also be reconsidered. Circular development becomes the organizing principle, and data monitoring and efficiency improvement alone are not enough for circular-economy implementation. Firms must also reconsider product-service arrangements and recovery channels [22–24,54,55], and partner roles and revenue logic may need to change as well.

Many studies examine how digital tools can support circular business-model renewal. Nascimento et al. [22] provide one of the earlier studies in the sample. They propose that Industry 4.0 technologies can help manufacturing firms implement a circular economy through business-model reconfiguration. De Giovanni [54] develops a theoretical model. The model combines blockchain and closed-loop supply chains. It also combines omnichannel reverse operations and cooperative incentives. The model shows that digital technologies can lower the cost of multi-party coordination in new circular business models. Alshibani et al. [55] propose that digital transformation and open innovation can jointly support circular business-model upgrading.

Lim et al. [23] study inter-firm digital platforms in China. They find that coordinated platform–ecosystem operation can improve circular-development outcomes. Meier et al. [24] use dynamic capabilities theory. They propose that blockchain can improve the overall management of circular supply chains. Multi-party cooperation and organizational reconfiguration are central to this effect.

These studies show that circular business models require ecosystem cooperation. They cannot be built by one firm acting alone. Product recovery and reuse depend on coordination among suppliers and consumers. Service providers and recycling firms also participate. Platform operators are another important actor. Digital platforms and blockchain systems can reduce information costs. Data-sharing arrangements can also reduce coordination costs. At the same time these arrangements create new governance requirements. Product-service integration and omnichannel reverse operations require changes in partner positioning. Circular purchasing and material-trading platforms require changes in customer relationships and profit logic. Resource-sharing arrangements can also change ecosystem rules [22–25,56].

This issue becomes more visible in digital-business settings, and a platform or e-commerce system can support the collection of used products. It can display product and material information and it can also verify green claims. Waste resources can be matched with users, and logistics and recycling partners can be coordinated through the same platform. Digital platforms therefore do more than support transactions, and they can provide trust and data-sharing infrastructure. They can also provide rule-based coordination for circular markets [23,25,42].

Compared with the first two mechanisms, the empirical base for business-model innovation is smaller. Findings are also less consistent. Khalife et al. [57] connect blockchain-based circular business models with SME performance. Bui et al. [25] show that digital-platform capability can support green innovation among Vietnamese SMEs. They also link this capability with circular-economy implementation. Gong et al. [56] use several cases to examine blockchain-enabled recycling networks. Piyathanavong et al. [58] show that internal developmental culture changes the relationship between Industry 4.0 and the circular economy. It also changes market competitiveness in Thai manufacturing firms. These studies are informative. Yet, much of the evidence comes from single cases or specific regions. Many studies focus only on SMEs or emerging markets.

Business-model innovation therefore has considerable theoretical potential. Its empirical foundation is also the weakest of the three mechanisms. Okorie et al. [42] call for more research on how digital transformation can support net-zero production models. They also call for research on competitive advantages in the circular economy. Shafique et al. [59] argue that work based on the natural-resource-based view has not fully explained circular business-model innovation. The remaining question is not only whether digital technologies can support circular business models. Researchers also need to examine digital-platform capability together with ecosystem collaboration. Organizational reconfiguration capability must be considered at the same time. Research should explain how firms build circular-development models that can be replicated across settings. It should also explain how these models can generate continuing returns.

4.3. Boundary Conditions Influencing Digital Transformation and Circular Economy Adoption

RQ2 examines the factors that change the relationship between digital transformation and circular-economy implementation and the synthesis shows that digital technologies do not automatically produce circular adoption. This remains true even when information transparency improves and higher resource efficiency is also not sufficient by itself. Better multi-party coordination does not guarantee adoption either, and outcomes depend on firm resources and managerial capabilities [24,26–29,33]. Institutional conditions and industry characteristics also matter, and supply-chain collaboration is another important factor. This review groups the boundary conditions into three categories, and they are firm-level conditions and institutional conditions. Industry and supply-chain conditions form the third category.

4.3.1. Firm-Level Conditions

Firm size is the most direct internal condition. Large firms are more likely to combine Industry 4.0 technologies with circular-economy models. SMEs with stronger resource bases also have an advantage. These firms usually have more financial resources. They also have specialist technical staff and mature management systems. Findik et al. [26] show that firm size changes how European SMEs use Industry 4.0 for circular development. Llach et al. [60] also identify firm size as an important factor. The factor matters when SMEs deploy blockchain and pursue circular transformation.

Very small firms can be flexible when adjusting their business and they often lack digital hardware and specialist talent. External knowledge absorption can also be difficult and studies of small firms therefore show that technology adoption may remain constrained after circular opportunities are recognized. The reviewed studies do not operationalize firm size in a consistent way and some use employee numbers or revenue. Others use firm type or technological maturity [26–29,60], and these differences make cross-country and cross-sector comparison more difficult. Firm size is therefore better

treated as a boundary condition and researchers should not assume that all small firms face the same disadvantage.

Managerial support and management models affect the integration of digitalization and the circular economy because leadership commitment shapes how technologies are used. Strategic attention and the willingness to allocate resources across functions also determine whether digital technologies support circular practices or only narrow operating goals. Change-oriented management can strengthen the use of digital twins and analytics while legitimacy and compliance concerns can motivate commitment to Industry 4.0-enabled circular initiatives [16,31,32,61].

Zheng et al. [61] study Chinese SMEs. They show that managers' views of compliant operation and industry reputation can affect willingness to use Industry 4.0 for circular-economy development. Other managerial and capability evidence in the corpus points in the same direction [31,32,53]. Circular transformation requires resource commitment and cross-functional coordination. It also requires acceptance of organizational adjustment. Evidence on managers' personal characteristics remains limited. Most of this evidence is context-specific. Its transferability across countries and sectors has not yet been established.

Knowledge absorption and digital application are also core internal factors. Firms that rely on digital technologies for their circular economy must first identify relevant digital knowledge. They must then absorb and use that knowledge. Khan et al. [31] show that big-data analytics capability can support green innovation in textile SMEs. The effect is stronger when it is combined with a data-driven management model. The same combination can improve circular-development outcomes. Anwar et al. [30] also find that big-data systems can improve decision quality. The improvement depends on the firm's ability to absorb and use new technological knowledge.

Wu and colleagues [32] propose that green digital transformation capability can support sustainable innovation when circular-economy readiness is present while Sahoo and colleagues [53] emphasize information acquisition capability and organizational ambidexterity. These capabilities connect Industry 4.0 technologies with circular-development outcomes and show that digital capability extends beyond a stock of hardware. Digital capability also reflects broader organizational capability, while most studies still treat absorptive capacity as a background condition or reference indicator. Few studies directly test how absorptive capacity changes the relationship between digital transformation and circular-economy implementation.

4.3.2. Institutional-Level Constraints

Research on institutional conditions is less extensive than work on firm operations and supply chains. It nevertheless helps explain regional variation in circular-economy outcomes. Firms operate under policies and regulation. They also face buyer requirements and professional norms. Industry rules can change adoption incentives and available resources [26,28,33,61]. They can also change the legitimacy of adoption. This review therefore treats institutional conditions as external boundary conditions. They are not capabilities owned by the firm.

European evidence shows that legal rules and market demand jointly shape digital–circular transformation while industry practices also play a role. Findik and colleagues [26] show that firm characteristics condition how European SMEs use Industry 4.0 for circular practices while manufacturing supply-chain cases provide related evidence on resilience and environmental adaptability. Industry 4.0-enabled coordination can ease institutional adjustment pressure [62] and these findings caution against transferring results across regulatory settings or firm populations.

Local industrial planning and government-led transformation programs in China can change the pace of digitalization and circular-economy initiatives [33,61] and they can also change the direction of these initiatives. Wang et al. [33] use a Delphi study to identify relevant policy measures and these measures connect Industry 4.0 technologies with circular-economy development in Chinese supply chains. The evidence suggests that firms deploy digital systems for internal improvement and they also use them to respond to external institutional expectations. Policy support alone cannot replace organizational capability and also cannot replace inter-firm coordination.

Institutional conditions also affect cross-firm digital platforms and platform collaboration models can change implementation outcomes. Data-sharing rules can do the same and supporting management arrangements also matter. These conditions determine whether greater supply-chain transparency reduces barriers to circular practices, and evidence from Chinese digital-platform settings shows that platform governance and policy support work together [23,33]. They should not be treated as fully independent drivers of circular outcomes.

Emerging markets such as Bangladesh and India also provide evidence on institutional pressure. Ecuador contributes a smaller body of evidence. The literature remains scattered [28]. Across the reviewed studies, external control requirements interact with technological readiness. Workforce capability also enters this relationship. Supply-chain arrangements are another part of the interaction. This helps explain why similar blockchain or Industry 4.0 applications lead to different circular-business-model choices. It also helps explain performance differences across emerging-market settings [17,28,29].

4.3.3. Industry and Supply Chain-Level Constraints

Industry characteristics and supply-chain operations can change the relationship between digital transformation and circular-economy implementation and industries differ in resource intensity and product structure. Waste generation also differs and technological capability and verification requirements vary across sectors. Regulatory exposure varies as well and the same digital technology can therefore face different implementation barriers in cement and electronics. Tires and energy provide other settings. Food and general manufacturing also create different constraints [12,13,63].

A firm's position in the supply-chain network is another central boundary condition. The cooperative capability of partners also matters. Circular-economy implementation requires reverse-logistics systems and resource-recovery channels. It also requires continuing coordination across upstream and downstream actors. Dynamic-capability evidence shows that blockchain can improve supply-chain management [24,62]. The final effect still depends on the overall network structure. Partner cooperation and governance of shared information are also important. A single firm should therefore not be treated as the only relevant unit of analysis.

5. Discussion

5.1. An Integrated Framework of Digital Transformation and Circular Economy Adoption

The integrated framework separates three analytical roles, and dynamic capabilities theory explains how firms convert digital resources into circular action. Sensing and seizing are part of this process and reconfiguring is also included. NRBV explains the value of internally developed green resources and strategic commitments [38], and pollution-prevention routines and product stewardship belong to this category. Managerial learning and resource orchestration also belong here, and institutional theory explains external coercive and mimetic pressure [41]. It also explains normative pressure, and regulation and buyer requirements are examples. Professional norms and competitor imitation are

also examples and these pressures shape adoption and legitimacy. They also affect the possibility of scaling circular practices and the reviewed evidence supports keeping the three roles separate. Information capability and green capability concern internal organizational processes [24,26,53,61]. Supply-chain reconfiguration also belongs to this side of the framework. Regulation and legitimacy concerns result in external contextual pressure. Stakeholder demands belong to the same external category.

The technology–organization–environment framework can also explain digital–circular transformation. The conventional resource-based view is relevant as well. Stakeholder theory offers another useful perspective. These approaches were not adopted as the core integrative lenses. The present review needs to explain organizational transformation processes. It also needs to explain the strategic value of internal green capability. External institutional pressure requires a separate explanation. The alternative perspectives are therefore treated as complementary. They are not treated as competing explanations [38–41].

Figure 2 summarizes the integrated logic by showing how internal green and digital capabilities provide the firm-level basis for action. Dynamic capabilities explain how opportunities are recognized and acted upon while also showing how those actions become embedded. External institutional pressures shape adoption incentives and legitimacy demands while also defining the constraints surrounding implementation.

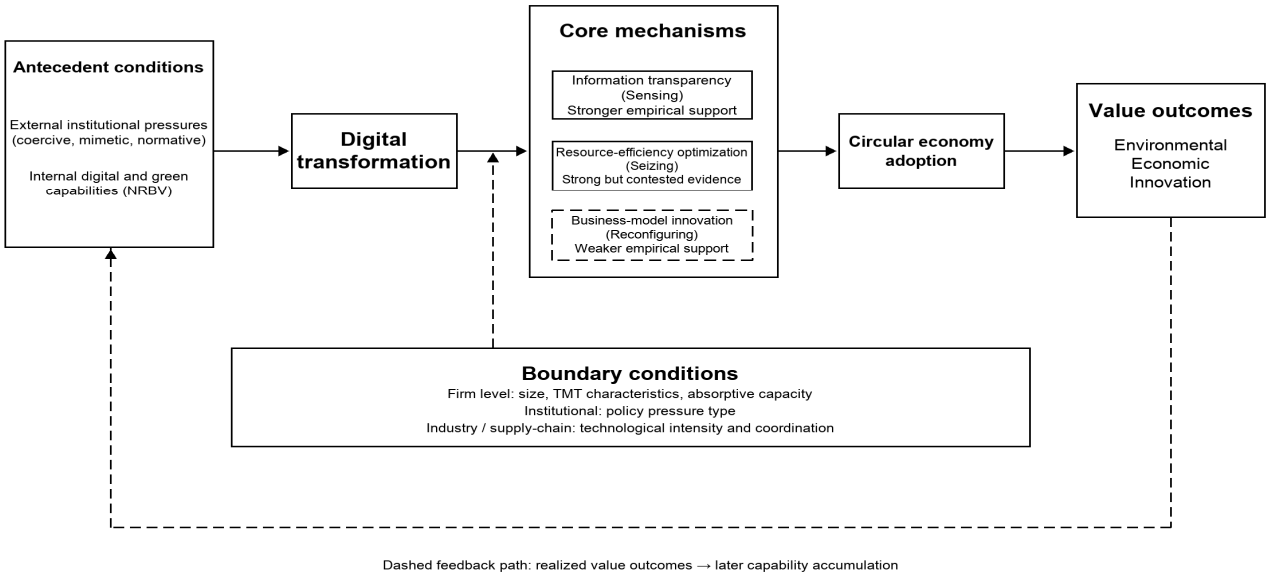


Figure 2. Integrative framework of digital transformation and circular-economy adoption. Source: Authors' 146-study synthesis; dashed elements indicate less-established or theoretical links.

The antecedent conditions in the framework must remain analytically separate because internal digital and green capabilities refer to resources and routines that firms develop and control. Data infrastructure and technical expertise belong to this category while managerial commitment and learning routines form another part of the internal capability base. Product-stewardship capability is another internal resource that contributes to the NRBV side of the explanation. External institutional conditions include coercive regulation and compliance demands while also covering mimetic responses to competitors and leading adopters. Normative expectations from professional bodies and buyers remain external conditions because they are contextual pressures rather than capabilities owned by the firm [26,28,61]. Civil-society expectations also belong to this external category because firms must respond to them rather than control them.

Dynamic capabilities connect these antecedents with circular action because data visibility and traceability can support sensing when firms have routines for interpretation.

Operational deployment can support seizing while changes in product-service systems and partner roles can support reconfiguration. Platform governance can also be reconfigured while the evidence shows that efficiency gains may remain local rather than uniformly positive. Rebound effects and weak complementary capabilities can limit broader sustainability gains [12,16], while weak governance can create the same problem [8,23,24].

Boundary conditions explain this variation because firm size and digital maturity affect how internal resources are used while managerial support and absorptive capacity shape implementation. Supply-chain coordination also matters because partner trust and data-sharing arrangements influence interorganizational implementation. Industry characteristics create further differences while regulatory enforcement and infrastructure shape the external institutional environment. Standards and stakeholder expectations can reinforce these conditions so a single technology should not be expected to create the same circular outcome in every context [24,26–29,33,61].

The framework treats environmental value as the most consistently documented outcome and it does not treat environmental value as an automatic result of digital investment. Evidence on economic and innovation outcomes is more fragmented and operational and social outcomes show the same pattern. Studies use different measures and time horizons, and they also examine different settings. The proposed feedback from realized circular value to later capability accumulation remains theoretical and longitudinal research is needed to test it [8,16,34,37].

From a digital-business perspective, the framework can also be read as an action sequence. Digital transformation first builds a data and platform base. This base helps firms see resources more clearly. It also helps firms use resources more carefully. Firms can then redesign business models around circular value. When the process works well, the outcome is not limited to better firm performance. Waste reduction is also only one part of the result. Public value may be created as well. Consumers and partners can obtain clearer information. Regulators and local communities can participate more easily in circular markets [23,25,42].

For managers the framework suggests a staged value-creation process and the first step is to connect product and process data. Customer and supplier data should also be connected and recycling data completes the sensing infrastructure. The second step is to turn information into seizing decisions, and firms can prioritize predictive maintenance and remanufacturing. Reverse logistics and green purchasing are other possible investments and closed-loop coordination also belongs to this stage. The third step is to reconfigure value creation, and firms can redesign product-service systems and partner incentives. Platform rules and data-sharing agreements may also need revision and digital tools are not the strategy itself. They create value only after they become embedded in routines, and governance mechanisms and inter-firm coordination systems are also required [12,14,17,23].

The managerial implication is not simply to increase spending on AI or blockchain because additional IoT and digital-platform investment is also insufficient. Managers should match each technology with a specific circular problem, while blockchain is most useful when trust and traceability are central. IoT and digital twins fit life-cycle monitoring and predictive maintenance while also supporting resource optimization. Big-data analytics and AI are useful when firms must interpret complex circular opportunities while digital platforms fit settings that depend on ecosystem participation. Secondary markets and product returns are typical examples while multi-actor coordination provides another application [12,14,16,23].

At the institutional level managers should treat regulation and stakeholder pressure as design conditions, and industry norms should not be treated only as background variables. Policy-led environments may require faster deployment of traceability systems

and reporting systems may also need to be built for compliance. Market-led environments may reward circular-platform innovation and customer trust and green differentiation may also receive a stronger return. The same digital capability can therefore produce different value outcomes and the difference depends on the structure of institutional pressure. It also depends on the maturity of the supply-chain ecosystem [28,33,61].

5.2. Critical Synthesis and Future Research Agenda

The evidence base should not be read as a simple technology-success story, and positive findings are common. Visibility and resource-monitoring outcomes are especially often positive and waste-reduction findings also tend to be favorable. Yet several studies report conditional or mixed effects [8,11,25,34–37], and null effects are also present. Cross-sectional self-report designs limit causal inference and inconsistent circular-economy measures also limit generalizability. Samples are concentrated in particular countries and sectors and publication bias may also be present. Successful technology-enabled transitions may be more likely to appear in the literature than failed implementations and future studies should report null and negative findings more often. Data and coding choices should also be made more transparent and comparative work should examine digital–circular configurations across institutional settings.

Table 4 summarizes the resulting research agenda. Each research gap is linked with a future direction. A recommended design is also provided. The methods include longitudinal and quasi-experimental approaches. Comparative institutional analysis is included as well. Multi-level supply-chain research is another direction. More comparable outcome measurement is also needed.

Table 4. Research gaps and future research agenda. Source: Prepared by the authors from the 146-study synthesis.

Gap	Description	Future Research Direction	Recommended Method
G1	CBM evidence weak	Circular platform value propositions	Multi-case theory building
G2	Rebound effects unclear	When and where rebound occurs	Quasi-experiment; DiD
G3	Few institutional comparisons	Europe–China-emerging markets	Comparative cases; HLM
G4	Little longitudinal evidence	Capability accumulation and long-term value	Panel data; repeated surveys
G5	Multi-level effects underexplored	Firm–industry–institution configurations	fsQCA
G6	Measures fragmented	Comparable CE adoption measures	Scale development; MGCFA
G7	Data sovereignty undertheorized	Ownership and access to circular data	Conceptual work; platform cases
G8	DPPs underexamined	DPPs as seizing/ reconfiguring triggers	Policy-shock designs; cases

5.2.1. Methodological Research Agenda

Future research needs stronger research designs. Much of the current evidence relies on cross-sectional surveys. Single-informant reports are also common. Case studies and expert assessments account for another part of the evidence [17,24,26,28]. Longitudinal designs can better separate genuine digital-to-circular effects from selection. Quasi-

experimental designs can address timing problems. Multi-method research can also reduce reporting effects.

First future studies should make greater use of quasi-experimental designs, and difference-in-differences can help identify causal effects. Propensity-score matching is another useful method and policy-shock designs can also clarify the effect of digital transformation on circular-economy adoption. Much of the present evidence relies on cross-sectional surveys and stronger identification strategies are therefore required. These strategies can address endogeneity and they can also separate genuine transformation effects from selection effects [16,17,31].

Secondly, longitudinal analysis and long-term tracking should become central methodological directions, and digital transformation is a dynamic process. Circular-economy adoption also unfolds over time and future studies can examine how firms accumulate digital capability. They can also examine how circular routines become institutionalized, and short-term implementation costs may later become environmental benefits. Economic and innovation outcomes may also emerge over a longer period and this direction is consistent with recent calls for more time-sensitive evidence on data-driven circular and recycling performance [64].

Thirdly, future research should develop more general and comparable measures of circular-economy implementation because existing studies use inconsistent indicators. Some studies rely on self-reported circular practices while others use resource-efficiency or waste-reduction measures and green innovation outcomes. This fragmentation limits cumulative knowledge while a validated scale or coding protocol would improve cross-study comparison and support a stronger meta-analysis. Future scale development should follow established procedures [65] with careful construct definition and item refinement followed by reliability and validity assessments.

5.2.2. Theoretical Research Agenda

Existing research does not fully explain how digital technologies enable circular operations and business-model renewal and many studies report an association between digital tools and circular practices. Few provide a detailed account of the underlying mechanism, and future research should examine how platform operating models interact with firm capabilities. This interaction must support recovery and reuse and it must also support multi-actor coordination and life-cycle data management. Researchers should distinguish circular platforms from conventional business platforms and they should explain how product-return requirements reshape value creation [22–24,42]. Material-reuse requirements should also be considered and ecosystem data requirements are another important element.

Future work should first define circular-platform value propositions more precisely before moving to empirical testing. Multiple-case theory building is well suited to this task [66] because interviews with platform operators and recyclers can reveal how coordination costs are reduced. Manufacturers and ecosystem partners should also be included so the research can explain how value from circular operations is sustained.

The relationship between digital transformation and circular competitive advantage remains under-specified despite evidence on dynamic capabilities and platform orchestration [23,42]. An integrated model is still needed to explain how digital resources and organizational routines jointly generate a circular advantage while accounting for business-model choices.

Future research should also refine institutional theory for policy-led emerging markets, and existing studies often use institutions only as background context. Research should separate coercive and mimetic pressures across different market systems and nor-

mative pressure should also be examined separately. Another important question concerns compliance-oriented digitalization and researchers should identify the conditions under which it becomes a strategic capability [28,33,61].

Comparative case designs and multi-level models can connect national institutions with firm-level circular implementation while extending the institutional framework of DiMaggio and Powell [41] to digital–circular transformation. Evidence from China shows that policy support can reduce barriers between digital technology use and circular development [33], while evidence from Bangladesh shows that institutional constraints interact with firm technological capability [28]. Together these conditions shape blockchain and circular-model choices while cross-country comparison can clarify how institutional configurations change digital–circular pathways.

Thirdly, future research should pay more attention to digital markets and public value and many current studies still focus on factories and supply chains. Production efficiency also dominates the discussion and these topics are important. They do not fully explain how digital platforms shape circular consumption and second-hand markets, and green trust also requires more attention. Data-based public governance is another important area and future research can examine platform rules and data openness. Privacy protection and green certification should also be considered and algorithmic recommendation may influence circular-economy adoption as well. This direction brings the discussion closer to digital-business research and also shows how digital transformation can create value beyond the boundary of a single firm [23,25,42].

A second theoretical extension concerns Circular Data Sovereignty. This review draws on the broader literature on data sovereignty and information-systems governance [67]. Circular Data Sovereignty is proposed as a future research construct. It is not presented as a fully established theory. In circular ecosystems, product and material data are generated by multiple actors. Repair and recycling data are also distributed across actors. The same applies to emissions data. Control over these data may still be concentrated in a few platform owners or focal firms. Future research should ask who owns circular data. It should also ask who can access and verify those data. The negotiation of data-sharing rules is another important question. These rules can change trust and participation in circular markets. Circular Data Sovereignty can therefore be treated as a governance condition. It may determine whether digital transparency becomes a public-value asset. It may instead become a private control mechanism.

Digital Product Passports also provide a promising research direction. Emerging product-information regimes create the relevant institutional setting. The EU Ecodesign for Sustainable Products Regulation is one example [68]. DPPs can turn product-level sustainability information into standardized digital infrastructure. Durability and repairability information can be included. Recyclability information can also be included. For firms in cross-border supply chains, DPPs may strengthen seizing capability. They can clarify which circular opportunities are commercially actionable. They can also clarify which opportunities are legally actionable. DPPs may strengthen reconfiguration as well. Firms may need to redesign data architectures and supplier coordination. Product documentation and after-use recovery systems may also need to change across borders.

Table 5 positions the present mechanism-based review against selected prior reviews by drawing on the broader review literature. The comparison separates topical coverage from integrated study-level evidence synthesis.

Table 5. Analytical positioning of the present review relative to selected prior reviews.

Representative Prior Review	Primary Focus	Analytical Emphasis	Difference from Present Review
Alsaoudi et al. [10]	Industry 4.0, circular economy, and sustainable performance	Technology–CE intersection and future directions	Three-theory, study-level mechanism–boundary-condition–outcome synthesis.
Neri et al. [9]	Digital technologies and the circular economy	Systematic review and research agenda	Explicitly separates mechanisms, conditions, and reported value outcomes.
Neto et al. [11]	Industry 4.0 and circular economy	Bibliometric and systematic mapping	Moves from broad mapping to traceable organizational evidence synthesis.
Hanelt et al. [6]	Digital transformation strategy and organizational change	Systematic review of transformation research	Links digital transformation specifically to circular-economy adoption.
Vial [7]	Digital transformation	Conceptual review and research agenda	Synthesizes digital–circular mechanisms, contexts, and outcomes.
Present review (N = 146)	Digital transformation and circular-economy adoption	Dynamic capabilities, NRBV, and institutional theory	Study-level traceability from coded studies to descriptive and interpretive synthesis.

Note. The table provides analytical positioning rather than a quality ranking of prior reviews. Full bibliographic details for the selected review studies are provided in the reference list. Source: Prepared by the authors based on the cited prior reviews and the present review synthesis.

6. Conclusions

This review addresses a central problem in the literature, where digital-transformation research and circular-economy research often describe technologies and practices separately. The organizational connection between them remains under-specified and this review integrates 146 peer-reviewed studies. It identifies three main mechanisms and these are information transparency and resource-efficiency optimization. Circular business-model innovation is the third mechanism, and firms and supply chains use these mechanisms to turn digital resources into circular practices. Environmental outcomes receive the most consistent support and operational and social outcomes are more heterogeneous. They are also more dependent on conditions, and innovation and economic outcomes show the same contextual dependence.

The theoretical contribution of this review is to integrate dynamic capabilities theory with NRBV and institutional theory while keeping their roles distinct. Dynamic capabilities theory explains sensing and seizing while also explaining reconfiguration, and NRBV clarifies the strategic value of internal green capabilities. Institutional theory explains coercive and mimetic pressures together with normative pressure while the practical contribution is a staged logic for managers. Firms should build reliable digital and green capabilities and match each technology with a specific circular problem. Data and incentives should be coordinated across partners while implementation should be adjusted to institutional demands.

This review has several limitations and the included studies differ in research design and measurement. Country and industry differences can also affect the synthesis, and cross-sectional evidence dominates the empirical base. Publication bias toward successful transitions is also possible and a further limitation concerns the seven reports retrieved during revision. Their usable full texts were not available at the original eligibility-assessment cut-off and they became available only after the 146-study coding matrix and thematic synthesis were complete. The seven reports are disclosed in Supplementary Table S3 and a future update should code them under a predefined protocol. They did not change the present analytic corpus, and the conclusions of this review therefore remain bounded by the 146 included studies. Future research should use stronger causal designs and longitudinal tracking, and mixed and null findings should be reported more often. Cross-country and ecosystem-level variation needs further examination and measures of circular value also need greater comparability.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jtaer21090305/s1, Table S1: List of the 146 included studies; Table S2: Study-level coding matrix, source traceability, and available evidence locators; Table S3: Revision-stage retrieval update; Table S4: Study-level design-sensitive quality appraisal; Supplementary SLR Materials: Preserved search scope and Boolean logic, transparently labeled reconstructed platform syntax, inclusion and exclusion criteria, PRISMA count summary at the original eligibility-assessment cut-off, report-identity reconciliation, revision-stage retrieval disclosure, and coding protocol.

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Data Availability Statement: The complete bibliographic details of all 146 studies in the frozen analytic corpus are provided in Supplementary Table S1. The study-level coding, source traceability, and available evidence locators supporting the synthesis are provided in Supplementary Table S2. Supplementary Table S3 documents the seven reports whose full texts became available during revision and were not incorporated into the present analytic corpus.

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

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