Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Circular Economy Practices toward Supply Chain Resilience: An Institutional Tension

Kien Tan Ha
Thuyloi University
Thanh Minh Thanh To
Ton Duc Thang University
Bang Nguyen-Viet
bangnv@ueh.edu.vn

University of Economics Ho Chi Minh City

Research Article

Keywords: Circular economy practices, Supply chain resilience, Supply chain flexibility, Supply chain collaboration, Natural resource-based view, Dynamic capabilities theory

Posted Date: November 17th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11602490/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

This study examines how circular economy practices (CEP) enhance supply chain resilience (SCR) through supply chain flexibility (SCF) and supply chain collaboration (SCC), and how regulatory pressure shapes these relationships. Drawing on the natural resource-based view (NRBV), dynamic capabilities theory (DCT), and institutional theory, the study tests an integrated framework using survey data from 326 C-level managers of manufacturing SMEs in Vietnam. Partial least squares structural equation modeling (PLS-SEM) is employed to assess the direct, mediating, and moderating effects. The findings reveal that CEP enhances SCR both directly and indirectly through the parallel mediation of SCF and SCC. However, regulatory pressure (RP) weakens the positive effects of both SCF and SCC on SCR. This study contributes to sustainable supply chain management research by explaining how circular economy practices foster resilience through complementary operational and relational capabilities. It further highlights the contingent role of RP, demonstrating that institutional conditions may constrain the resilience benefits derived from these capabilities.

1. Introduction

In an era characterized by unprecedented systemic disruptions and macro-environmental uncertainty, global supply chains are increasingly vulnerable to structural shocks (Katsaliaki et al., 2022). Traditional linear take-make-dispose production models have proven increasingly vulnerable to compound global disruptions, forcing organizations to seek strategic defensive mechanisms through circular economy practices (CEP) and industrial symbiosis (Karman et al., 2024). Beyond mere ecological compliance, CEP enables a heterogeneous network of actors to collaboratively exchange by-products, water, and energy, thereby diversifying supply bases and mitigating exposure to volatile primary resource markets (Ali, 2025; Marsh et al., 2026). In emerging and developing economies, where manufacturing sectors face severe raw material scarcity and global decarbonization mandates (Leão & Pereira, 2026; Malik et al., 2022), adopting CEP has transformed from an optional corporate social responsibility initiative into an urgent imperative for operational survival and competitive advantage (Baah et al., 2023).

Despite the strategic promise of CEP in building organizational resilience, the process of developing these sustainable pathways is deeply embedded in and contingent upon the institutional environment (Sharma & Sharma, 2026). Classical institutional theory posits that external pressures (coercive, normative, and mimetic), uniformly drive the adoption of sustainable practices (Goulder & Parry, 2008). However, this linear assumption encounters a critical paradox during economic disruptions, particularly when firms face acute resource constraints (Boso et al., 2017). While rigid deterrence policies (e.g., command-and-control instruments and punitive carbon/environmental taxes) can inadvertently drain essential financial resource slack (Boso et al., 2017). Under extreme environmental dynamism, this resource depletion risks triggering threat-rigidity, forcing resource-constrained firms into symbolic compliance or defensive cost-cutting rather than substantive circular innovation (Chebbi & Arfa, 2025; Chen & Hatani, 2026).

Concurrently, grounded in the natural resource-based view (NRBV), CEP serves as an internal catalyst for strategic change by internalizing environmental imperatives (Ali, 2025). Yet, recent scholarship stresses that the mere possession of physical symbiotic infrastructure constitutes a static resource that does not automatically yield organizational resilience (Agyabeng-Mensah et al., 2021; Sharma & Sharma, 2026). Managing non-traditional, highly variable material streams (such as industrial waste and secondary residues) requires firms to continuously sense, seize, and reconfigure competencies (Karman et al., 2024). According to dynamic capabilities theory (DCT), this reconfiguration manifests through specific organizational routines, namely supply chain flexibility (SCF) and supply chain collaboration (SCC) (Bag & Rahman, 2023; Karman et al., 2024). While extant literature has examined the circularity-resilience nexus primarily within European or developed contexts (Boom-Cárcamo & Peñabaena-Niebles, 2026; Malik et al., 2022), there remains a critical theoretical gap regarding how dynamic capabilities mediate this relationship under contrasting institutional conditions, specifically when navigating the deterrence in developing economies (Boso et al., 2017; Sharma & Sharma, 2026).

To address these intertwined theoretical and contextual gaps, this study develops an integrated framework combining NRBV, and DCT to examine the institutional boundary conditions of CEP-driven resilience. Specifically, this paper investigates: (1) How do CEP practices foster dynamic capabilities (SCF and SCC) to enhance organizational resilience during crises? and (2) How does regulatory pressure (RP) moderate the effects of SCF and SCC on organizational resilience in the context of resource-constrained firms in an emerging market?

This study offers three key contributions. First, it advances the circular economy literature by unpacking the black box between physical symbiotic exchanges and long-term organizational resilience through the mediating lens of dynamic capabilities (Karman et al., 2024). Second, it extends institutional theory by empirically testing the boundary conditions of regulatory pressure, highlighting how institutional enablers condition corporate responses to environmental pressure (Boso et al., 2017). Finally, it provides practical and policy insights for managers and policymakers in emerging economies seeking to design effective policies that foster resilient industrial eco-parks without compromising firm survival.

2. Theoretical framework and hypothesis development

2.1 Theory framework

This study develops an integrated conceptual model grounded in the NRBV, DCT, and institutional theory. This multi-lens approach provides a holistic understanding of how circular practices are converted into resilience and how this process is contingent upon the institutional environment (e.g. Le et al., 2023; Mensah et al., 2025). NRBV (Ozbekler & Ozturkoglu, 2020) extends the traditional resource-based view by arguing that a firm's competitive advantage is increasingly linked to its ability to manage activities in harmony with the natural environment (Horbach et al., 2023). CEP is conceptualized here as strategic resources that allow firms to decouple economic growth from material consumption by closing resource loops (Fric et al., 2025). According to NRBV, proactive engagement in CEP enables organizations to

internalize environmental imperatives, thereby creating unique, inimitable advantages through optimized resource utilization and waste-to-feedstock conversion (Ali et al., 2025). DCT provides the how, the process of sensing opportunities and reconfiguring these resources into operational resilience (Teece et al., 1997). Dynamic capabilities serve as a pivotal mechanism for transforming circular resources into practical innovative behaviors to address environmental disruptions (Mensah et al., 2025). In the absence of these capabilities, circular practices are unlikely to generate the necessary cushions or strategic buffers required for an organization to weather shocks and maintain long-term viability.

Drawing on institutional theory, organizational behavior is significantly shaped by external pressures and the overall regulatory landscape (Chu et al., 2018). This study posits that the effectiveness of building dynamic capabilities from CEP is moderated by the type of institutional intervention (Sharma & Sharma, 2026). Deterrence policies as regulatory pressure (RP), characterized by rigid command-and-control instruments like environmental taxes, may impose heavy financial burdens (Goulder & Parry, 2008). Under crisis conditions, such deterrence measures risk draining slack resources, the essential buffers required for innovation and reconfiguration (Boso et al., 2017). Therefore, deterrence policies may paradoxically weaken the link between dynamic capabilities and resilience by hindering the organization's ability to maintain the necessary cushions for post-disruption recovery (Sharma & Sharma, 2026).

2.2 Hypothesis development

2.2.1 The impact of CEP on SCF, SCC

CEP is defined as a collaborative paradigm involving the exchange of energy, materials, water, and by-products among traditionally separate entities to achieve a competitive advantage (Chertow, 2007). Under this framework, the waste or residues of one organization serve as valuable feedstocks for another (Yazan & Fraccascia, 2020). This framework serves as a key meso-level mechanism for the circular economy (Fric et al., 2025). SCF is a dynamic capability that helps a supply chain respond to changes and uncertainties in the market (Bag & Rahman, 2023). It also helps the supply chain maintain cost-effectiveness and operational efficiency. SCF also reflects the ability of the supply chain network to anticipate and adapt to changes. It allows the supply chain to adjust its resources when needed. These resources include production volume, product mix, sourcing strategies, and delivery schedules (Sharma et al., 2023). SCC is a process where different supply chain partners work together to achieve shared goals (Liao et al., 2017). These partners can include suppliers, manufacturers, distributors, and customers. They share their resources, knowledge, and information to improve supply chain performance. SCC also helps partners achieve mutual benefits and gain competitive advantages that they may not achieve when working independently (Mubarik et al., 2025).

Drawing on the NRBV, environmental imperatives are not viewed as constraints but as the basis for creating unique strategic resources (Chu et al., 2018). By utilizing waste and by-products as alternative inputs, firms can effectively diversify their supply base and reduce their strategic dependence on volatile primary material markets (Malinauskienė et al., 2018). However, managing non-traditional and highly

uncertain material streams (e.g., waste) requires organizations to move beyond rigid structures. According to DCT, CEP compels firms to continuously reconfigure their internal operational routines and production configurations to accommodate the inherent variability of secondary resources (Ellström et al., 2021). This ongoing process of reconfiguration fosters organizational flexibility, enabling firms to adjust production timeframes and systems to handle alternative materials efficiently (Bah & Rahman, 2023; Karman et al., 2024).

Simultaneously, the inherent nature of CEP involves a high level of inter-organizational interdependence between independent entities (Tang et al., 2021). To effectively integrate these exogenous resources, firms must transcend traditional boundaries and engage in deep cross-sectoral partnerships (Filimonau & Ermolaev, 2022). DCT suggests that the successful absorption of these external resources is contingent upon the organization's ability to develop sensing and information-sharing capabilities with diverse partners (Dubey et al., 2024; Karman et al., 2024). This process strengthens the collaborative infrastructure of the supply chain, facilitating risk-sharing and the institutionalization of trust within the network (Mubarik et al., 2025). Consequently, the commitment to industrial symbiosis acts as a catalyst for profound supply chain engagement (Baah et al., 2023). Therefore, we propose:

H1a: CEP have a positive impact on SCC

H1b: CEP have a positive impact on SCF

2.2.2 The impact of SCF and SCC on SCR

SCR is defined as the adaptive capability of a supply chain to prepare for, anticipate, withstand, adapt to, and rapidly recover from unpredictable disruptive events to maintain operational continuity and performance (Ponomarov & Holcomb, 2009; Yao & Fabbe-Costes, 2018). Organizational survival in turbulent environments does not depend on static asset possession but on core competencies that allow for rapid reconfiguration (Yu et al., 2019). SCF serves as a critical dynamic mechanism that enables organizations to adjust logistics networks and identify alternative local materials when global supply chains are severed (Bag & Rahman, 2023; Karman et al., 2024). Specifically, flexibility in sourcing allows firms to switch instantaneously to secondary suppliers or recycled materials from industrial symbiosis partners without halting production lines. By fostering the ability to reconfigure production schedules and resource allocations, flexibility acts as a buffer against supply-side shocks, directly enhancing the system's resilience (Bag et al., 2019).

SCC, characterized by trust and relational governance, allows firms within a symbiotic network to share risks and institutionalize mutual support (Mubarik et al., 2025). Strong collaborative linkages facilitate the exchange of real-time information and early warning signals regarding pending disruptions, enabling partners to collectively reallocate shared resources or provide financial and technical assistance during crises (Cao et al., 2026; Mubarik et al., 2025). According to DCT, collaboration transcends internal boundaries to leverage external relational assets, providing organizations with significant redundancy and adaptive capacity (Mensah et al., 2025). This collective response mechanism is fundamental for

absorbing negative impacts and accelerating the recovery process after a shock (Karman et al., 2024). Therefore, we propose:

H2a: SCC has a positive impact on SCR.

H2b: SCF has a positive impact on SCR

2.2.3 The mediating role of SCC and SCF

Although CEP can create opportunities for supply chain resilience, its benefits may not translate directly into SCR. The effective utilization of alternative resources generated through CEP requires firms to develop both relational and operational capabilities (Jiao et al., 2022). In this regard, SCC and SCF represent two complementary mechanisms through which CEP enhance performance improvements (Zhu et al., 2012).

CEP inherently increases interdependence among participating organizations because waste, by-products, energy, and other secondary resources are exchanged across organizational boundaries. From the NRBV perspective, these alternative resource flows can become strategic resources when firms develop the capabilities required to effectively access and utilize them (Hart, 1995; Chu et al., 2018). However, effective resource exchange requires information sharing, mutual support, joint planning, and coordination among partners. Thus, CEP can strengthen SCC by encouraging firms to establish deeper inter-organizational relationships and mechanisms for resource and knowledge sharing (Liao et al., 2017; Mubarik et al., 2025). In turn, SCC facilitates the exchange of information, risk sharing, and collective responses during disruptions, thereby enhancing the supply chain's ability to absorb and recover from unexpected events (Cao et al., 2026; Mubarik et al., 2025). Therefore, SCC can serve as a relational mechanism that translates the inter-organizational resource benefits of CEP into greater resilience. Hence:

H3: SCC mediates the positive relationship between CEP and SCR.

CEP also requires firms to manage secondary resource streams that may vary in availability, quality, timing, and volume. According to DCT, continuously dealing with such variability encourages firms to reconfigure their sourcing, production, and logistics routines (Ellström et al., 2021). As firms gain experience in managing alternative resource flows, they can develop greater flexibility in sourcing, production planning, and resource allocation. SCF consequently enables firms to switch suppliers or resource sources, adjust production schedules, and reallocate resources when conventional supply channels are disrupted (Bag et al., 2019; Bag & Rahman, 2023). Thus, SCF provides an operational mechanism through which CEP's resource diversification can be transformed into greater resilience. Hence:

H4: SCF mediates the positive relationship between CEP and SCR.

Furthermore, SCC and SCF represent complementary pathways through which CEP can influence SCR. SCC provides the relational infrastructure for accessing information, knowledge, and external resources, whereas SCF enables firms to reconfigure these resources within their operations. From a DCT perspective, resilience depends on both the ability to coordinate external resources and the ability to rapidly reconfigure internal activities. Accordingly, CEP is expected to enhance SCR through the combined indirect effects of SCC and SCF (Nguyen-Viet et al., 2026). Therefore:

H5: The relationship between CEP and SCR is mediated by the combined indirect effects of SCC and SCF.

2.2.4 The moderating role of regulatory pressure

Beyond internal determinants, organizational behavior and structures are profoundly shaped by pressures from the institutional environment (Dai et al., 2021). In the context of industrial symbiosis, government policy interventions function as critical external forces that reconfigure a firm's operational strategies (Wang et al., 2022). Maintaining stringent deterrence policies during a crisis may directly deplete these essential cushions, potentially paralyzing the organization's ability to adapt and maintain performance post-disruption, thereby weakening SCR (El Baz & Ruel, 2021).

Deterrence mechanisms such as environmental taxes and stringent penalties are traditionally expected within Institutional theory to create significant compliance costs. These costs are theorized to overcome organizational inertia and compel firms to optimize their internal systems (Chu et al., 2018). This perspective, often aligned with the Porter hypothesis, suggests that well-designed environmental regulations can trigger innovation and proactive environmental stewardship (Rousselière et al., 2024). However, examining this relationship through the NRBV lens within the context of global supply chain disruptions reveals limitations of traditional institutional logic (Dubey etl., 2024; Karman et al., 2024; Rousselière et al., 2024).

SMEs are characterized by limited technical staff, constrained investment capacity, and high uncertainty regarding both compliance requirements and the returns on circular investments (Sharma & Sharma, 2026). During periods of systemic crisis, function as an essential survival buffer that allows organizations to maintain SCF and uphold SCC commitments within their networks (Boso et al., 2017).

Maintaining stringent deterrence policies during disruptions effectively imposes a double burden on SMEs (Sharma & Sharma, 2026). This resource depletion erodes the necessary financial cushions and slack resources required to operationalize dynamic capabilities. Instead of functioning as an innovation trigger, excessive regulatory pressure during a crisis may induce threat-rigidity, where firms focus solely on survival rather than adaptation (Dankyira et al., 2024). Consequently, deterrence policies act as a barrier that hinders the process of converting dynamic capabilities (SCF and SCC) into SCR. Based on these arguments, we propose:

H6a: RP negatively moderates the relationship between SCC and SCR, such that the positive effect of SCC on SCR is weaker at higher levels of RP and stronger at lower levels of RP

H6b: RP negatively moderates the relationship between SCF and SCR, such that the positive effect of SCF on SCR is weaker at higher levels of RP and stronger at lower levels of RP

3. Research methodology

3.1. Research design and instrument development

The unit of analysis is defined at the firm level. The study focuses on small and medium-sized manufacturing enterprises (SMEs) located in Ho Chi Minh City, Binh Duong, and Dong Nai, which are among the major industrial hubs in Vietnam. Data were collected from SMEs operating in these areas. Following the guidelines of Crick and Crick (2025), a purposive convenience sampling approach was employed to recruit C-level executives who are directly involved in strategic decision-making and possess in-depth knowledge of their organizations' operations, business environment, and strategic direction. To gain access to them, the list of companies was typically compiled from databases maintained by regulatory authorities (such as the Ho Chi Minh City Export Processing and Industrial Zones Authority - HEPZA) or by industry associations (such as APICS, ISM, CSCMP, BGMEA, and associations representing SMEs). To minimize potential measurement errors, the instrument was designed to capture focal constructs that are consistent with those examined in recent experiential circular economy research (e.g., Bag & Rahman, 2023; Sharma & Sharma, 2026). The respondents included senior managers, operations managers, and sustainability-related professionals who had substantial knowledge of their firms' strategies and industrial symbiosis practices. The study adopts a quantitative, cross-sectional design. Primary data were collected through an online questionnaire using five-point Likert scales (1 = strongly disagree; 5 = strongly agree), with measurement items adapted from previous studies. Specifically, the measurement scales for CEP adopted from Rodríguez-González et al. (2022). SCF and SCC were adopted from Karman et al. (2024), the SCR scale was adapted from El Baz & Ruel (2021), and RP scales were derived from Sharma and Sharma (2026).

The questionnaire development process incorporated a back-translation procedure (Brislin, 1970) and a pilot test involving 40 respondents to refine the wording and ensure the clarity of measurement items. Partial least squares structural equation modeling (PLS-SEM) was selected as the primary analytical technique (Hair et al., 2026a). This technique was adopted for three main reasons: (1) its ability to effectively estimate complex research models involving multiple moderating relationships simultaneously; (2) its suitability for prediction-oriented research with moderate sample sizes; and (3) its ability to explicitly account for measurement error (Hair et al., 2026b). In addition, the use of PLS-SEM in this study was intended to address several methodological limitations associated with its application, as highlighted by Wang et al. (2024), particularly in the reporting of PLS-SEM analyses in the logistics and supply chain management literature.

3.2 Common method bias

Although common method variance is a potential concern with self-reported data, recent evidence suggests that its impact may be limited (Cui et al., 2026). Nevertheless, to further mitigate potential

common method bias, several procedural remedies were implemented, including ensuring respondent anonymity, randomizing the order of questionnaire items, and informing participants that there were no right or wrong answers to their responses (Podsakoff et al., 2024). Harman's one-factor test was conducted to assess the potential presence of common method bias. The results indicated that the first factor accounted for 35.14% of the total variance. Moreover, the random dependent variable–full collinearity test was employed to further assess the potential presence of common method bias (Castillo et al., 2026; Kock, 2015). The results revealed that the variance inflation factor values ranged from 1.785 to 2.202, all of which were below the conservative threshold of 3.33, suggesting that common method bias was unlikely to represent a critical concern in this study.

4. Research results

4.1. Demographic characteristics of the research sample

A total of 326 valid responses were collected during January 2026 and retained for the final analysis. Table 1 summarizes the demographic characteristics, specifically, 84.97% of the participants had more than five years of working experience, with the majority holding key positions related to supply chain management, including supply chain-logistics managers (34.97%) and production-operations managers (30.06%). From an organizational perspective, the sample covers major manufacturing sectors in Vietnam, including textiles and footwear (25.15%), food and beverages (19.94%), and electronics (18.10%). More than 89% of the surveyed firms had been operating for over five years, and the majority were classified as SMEs.

Table 1
Demographic characteristics of the research sample

Characteristics	Classifications	Frequency	Percentage (%)
Industry sector	Textiles & Apparel	82	25.15
	Food & Beverage	65	19.94
	Electronics & Electrical	59	18.10
	Chemicals & Plastics	49	15.03
	Metal & Machinery	39	11.96
	Others	32	9.82
Firm size	< 50 employees	81	24.85
	50–200 employees	245	75.15
Years of operation	< 5 years	33	10.12
	5–10 years	114	34.97
	11–15 years	98	30.06
	> 15 years	81	24.85
Respondent's position	Board of Directors	65	19.94
	Logistics Manager	114	34.97
	Production Manager	98	30.06
	Sustainability Manager	49	15.03
Working experience	< 5 years	49	15.03
	5–10 years	130	39.88
	11–15 years	98	30.06
	> 15 years	49	15.03

[Table 1]

4.2 Measurement model

The measurement model was first assessed for reliability and convergent validity using outer loadings, Cronbach's alpha, and average variance extracted (AVE). As reported in Table 2, all item loadings exceeded the recommended threshold of 0.70, while Cronbach's alpha values for all constructs (CEP, SCF, SCC, SCR, and RP) were above 0.70, confirming satisfactory internal consistency. In addition, AVE values ranged from 0.621 to 0.779, exceeding the 0.50 threshold for all constructs. Overall, these results support the reliability and convergent validity of the measurement model.

Table 2
Reliability and convergent validity assessment of the measurement model

Construct	Item	Loading	Alpha	AVE
Circular Economy Practices (CEP)	CEP1	0.849	0.867	0.621
	CEP2	0.872		
	CEP3	0.886		
	CEP4	0.818		
	CEP5	0.817		
Supply Chain Collaboration (SCC)	SCC1	0.908	0.902	0.773
	SCC2	0.902		
	SCC3	0.827		
	SCC4	0.878		
Supply Chain Flexibility (SCF)	SCF1	0.907	0.905	0.779
	SCF2	0.871		
	SCF3	0.913		
	SCF4	0.838		
Regulatory Pressure (RP)	RP1	0.870	0.899	0.765
	RP2	0.889		
	RP3	0.834		
	RP4	0.903		
Supply Chain Resilience (SCR)	SCR1	0.848	0.903	0.722
	SCR2	0.897		
	SCR3	0.796		
	SCR4	0.875		
	SCR5	0.830		

[Table 2]

We employed bootstrapping with 10,000 subsamples in SmartPLS to assess discriminant validity using the heterotrait-monotrait (HTMT) ratio with a 95% confidence interval (Roemer et al., 2021). As shown in Table 3, all HTMT values were below the recommended threshold of 0.85 (0.025–0.699), and none of the

corresponding confidence intervals included 1. These results provide evidence of adequate discriminant validity, indicating that the latent constructs are empirically distinct from one another.

Table 3
The HTMT criterion (full dataset)

Correlation	HTMT ratio	95% PBCI
RP*SCC -> CEP	0.085	[0.026; 0.192]
RP*SCF -> CEP	0.064	[0.018; 0.112]
RP*SCF -> RP*SCC	0.587	[0.462; 0.688]
RP -> CEP	0.047	[0.031; 0.047]
RP -> RP*SCC	0.025	[0.004; 0.038]
RP -> RP*SCF	0.077	[0.020; 0.212]
SCC -> CEP	0.657	[0.571; 0.730]
SCC -> RP*SCC	0.119	[0.031; 0.257]
SCC -> RP*SCF	0.077	[0.023; 0.197]
SCC -> RP	0.035	[0.022; 0.032]
SCF -> CEP	0.676	[0.586; 0.749]
SCF -> RP*SCC	0.080	[0.021; 0.202]
SCF -> RP*SCF	0.026	[0.003; 0.037]
SCF -> RP	0.061	[0.025; 0.084]
SCF -> SCC	0.602	[0.507; 0.684]
SCR -> CEP	0.511	[0.389; 0.616]
SCR -> RP*SCC	0.470	[0.353; 0.581]
SCR -> RP*SCF	0.425	[0.287; 0.537]
SCR -> RP	0.090	[0.042; 0.196]
SCR -> SCC	0.699	[0.604; 0.771]
SCR -> SCF	0.615	[0.503; 0.703]
Note: PBCI = percentile bootstrap confidence interval (one-sided test)		

[Table 3]

4.3 Structural assessment

Structural model analysis was conducted to examine the relationships among the five latent constructs. The research hypotheses were represented as structural paths in Fig. 1, together with the standardized path coefficients, the effect sizes of the explanatory variables on the endogenous constructs (f^2), and the explanatory power of the model (R^2).

The results indicate that the relationships between CEP and SCC (β = 0.577, t = 15.507, f^2 = 0.500), CEP and SCF (β = 0.616, t = 16.729, f^2 = 0.612), SCC and SCR (β = 0.418, t = 9.196, f^2 = 0.299), and SCF and SCR (β = 0.312, t = 6.690, f^2 = 0.156) are all significant at the 0.001 level. Therefore, hypotheses H1a, H1b, H2a, and H2b are supported. We employ explicit approaches to mediation analysis (Bozkurt et al., 2026). The mediation analysis indicates that SCC and SCF significantly mediate the relationship between CEP and SCR through parallel mediation. Specifically, the specific indirect effects through SCC (β = 0.244, t = 8.120) and SCF (β = 0.192, t = 6.272) are both significant. The total indirect effect of CEP on SCR through the two parallel mediators is also significant (β = 0.436, t = 11.282). However, the direct effect of CEP on SCR is not significant (β = 0.002, t = 0.040). Following Zhao et al. (2010) and Hair et al. (2026a), these results indicate indirect-only mediation, suggesting that the effect of CEP on SCR is transmitted through SCC and SCF. Thus, hypotheses H3, H4, and H5 are supported.

Moderation analyses were rigorously conducted based on recent recommendations (To, 2026; Memon et al., 2026). To assess the moderating effects, the two-stage approach proposed by Becker et al. (2018) was employed. First, estimating the baseline model & calculating latent variable scores. Then, creating interaction terms & estimating the full model. Although the two-stage approach may introduce multicollinearity in the structural model due to the presence of interaction terms, PLS-SEM is fairly robust against this issue (Xu & Shiau, 2026). The results show that the interaction effects of SCC*RP on SCR (β = -0.246, t = 4.205, f^2 = 0.110), and SCF*RP on SCR (β = -0.223, t = 3.896, f^2 = 0.097) are also statistically significant at the 0.001 level. Accordingly, hypotheses H6a, H6b are supported. To ensure the robustness of these findings, the confidence intervals for each relationship were examined. The bootstrapping results indicate that none of the confidence intervals included zero (see Table 5), confirming the statistical significance and robustness of the estimated effects. To determine the role of the moderating variables, we performed moderation regression analysis (Söderlund, 2023). The results showed that the direct effects of RP (β = -0.098, t = 1.121, p = 0.262) on SCR were not statistically significant, confirming that RP are pure moderating variables (To, 2026).

Table 5
Results of the direct, indirect, and moderating effects hypothesis testing

Hypothesis	Relationship	Path (*t*-value, *p*-value)	St.Dev.	95% PBCI	f^2	Support
H1a	CEP -> SCC	0.583 (16.137, 0.001)	0.036	[0.505; 0.648]	0.515	Yes
H1b	CEP -> SCF	0.613 (16.463, 0.001	0.037	[0.535; 0.680]	0.602	Yes
H2a	SCC -> SCR	0.419 (8.876, 0.001)	0.047	[0.322; 0.508]	0.298	Yes
H2b	SCF -> SCR	0.314 (0.046, 0.001)	0.046	[0.214; 0.401]	0.159	Yes
	Indirect effect					
H3	CEP -> SCC-> SCR	0.244 (8.120, 0.001)	0.030	[0.185; 0.302]		Yes
H4	CEP -> SCF-> SCR	0.192 (6.272, 0.001)	0.031	[0.133; 0.254]		Yes
	Total Indirect effect					
H5	CEP -> SCR	0.436 (11.282, 0.001)	0.039	[0.360; 0.511]		Yes
	Moderating effect					
H6a	SCC*RP -> SCR	-0.246 (4.144, 0.001)	0.059	[-0.347; -0.155]	0.110	Yes
H6b	SCF*RP -> SCR	-0.223 (4.030, 0.001)	0.055	[-0.323; -0.133]	0.097	Yes

Source: Authors' own work

Regarding the explanatory power of the structural model, the endogenous constructs achieved R^2 values of 33.3% for SCC, 38.0% for SCF, and 64.8% for SCR, indicating moderate to substantial explanatory power. In addition, we assessed the out-of-sample predictive relevance of SCR using the PLS predict procedure (Hair et al., 2026b). The results show that all Q^2 predict values are greater than zero. Furthermore, since the RMSE values of PLS-SEM are lower than those of the linear model (LM), the model demonstrates high predictive power for SCR (Hair et al., 2026a; see Table 4).

Table 4
PLS predict analysis results.

Supply chain resilience	$Q^2_{predict}$	$RMSE_{PLS-SEM}$	$RMSE_{LM}$	$RMSE_{PLS-SEM}$ - $RMSE_{LM}$
SCR1	0.304	0.741	0.760	-0.019
SCR3	0.258	0.803	0.818	-0.015
SCR5	0.265	0.769	0.787	-0.018
SCR2	0.319	0.720	0.733	-0.013
SCR4	0.315	0.730	0.733	-0.003
Source: Authors' own work				

[Table 4]

[Table 5]

[Figure 1]

5. Discussion and implications

5.1 Discussion

The findings provide empirical evidence that CEP enhances supply chain resilience through the development of collaborative and flexible capabilities (Sudusinghe & Seuring, 2022). Specifically, the results confirm that CEP significantly and positively influences both SCC and SCF, while SCC and SCF, in turn, positively contribute to SCR. The significant indirect effects further demonstrate that SCC and SCF serve as important mediating mechanisms in the relationship between CEP and SCR, supporting the argument that the resilience benefits of circular practices are realized through organizational capability development.

The positive relationship between CEP and SCC reflects the inherently inter-organizational nature of industrial symbiosis. CEP requires firms to exchange by-products, energy, materials, and other resources across organizational boundaries, which creates a need for information sharing, coordination, trust, and joint problem-solving (Ali et al., 2025). Thus, CEP can strengthen collaborative relationships by increasing interdependence among participating firms. This finding is consistent with Chertow (2007), who emphasize that industrial symbiosis generates value through coordinated resource exchanges and inter-firm collaboration.

The positive effect of CEP on SCF further indicates that engaging in circular resource exchanges encourages firms to develop greater operational adaptability. The use of secondary materials and by-products requires firms to adjust sourcing arrangements, production processes, and resource allocation

in response to variations in resource availability and quality. Consequently, CEP can strengthen firms' ability to reconfigure operational resources and respond to changing supply conditions. This result is consistent with previous studies highlighting flexibility as an important capability for managing uncertainty and supply disruptions (Edwin Cheng et al., 2022; Bag & Rahman, 2023).

The findings also confirm the positive effects of both SCC and SCF on SCR. SCC enables supply chain partners to share information, coordinate responses, pool resources, and provide mutual support during disruptions, thereby facilitating collective adaptation and recovery (Yu et al., 2019; Mubarik et al., 2025). Similarly, SCF enables firms to adjust sourcing, production, logistics, and resource allocation when normal supply arrangements are disrupted (Kazancoglu et al., 2022; Karman et al., 2024). These results reinforce the view that resilience is supported by the continuous development and reconfiguration of both relational and operational capabilities.

Importantly, the significant mediation effects provide further insight into how CEP contributes to SCR. The mediating role of SCC indicates that the resilience benefits of CEP are partly realized through stronger inter-organizational collaboration, whereas the mediation through SCF demonstrates that these benefits are also transmitted through greater operational flexibility. Moreover, the significant combined indirect effect of SCC and SCF suggests that these two capabilities jointly constitute important pathways linking CEP to SCR. This finding highlights the complementary roles of relational coordination and operational adaptability in transforming circular resource practices into resilience outcomes (Nguyen-Viet et al., 2026).

Finally, the negative moderating effect identified in the model indicates that the institutional mechanism examined in this study weakens the positive relationship between CEP and SCR. This result is consistent with the hypothesized direction and suggests that, under stronger levels of the relevant institutional pressure, the positive resilience benefits associated with CEP become less pronounced. Rather than eliminating the positive contribution of CEP, the negative moderation indicates that institutional conditions can constrain the extent to which firms are able to translate circular practices into resilience outcomes. This finding highlights the importance of considering the institutional context in which CEP is implemented, as organizational capabilities may generate different resilience outcomes depending on the intensity of external institutional pressures.

Overall, the findings demonstrate that CEP contributes to SCR not only through circular resource utilization but also through the development of SCC and SCF. The results therefore reinforce the importance of viewing CEP as a capability-building mechanism through which firms strengthen both collaborative relationships and operational adaptability, while also showing that the institutional context can influence the strength of these resilience benefits.

5.2 Theoretical implications

First, this study extends the NRBV by showing that the strategic value of circular practices extends beyond resource efficiency and environmental benefits. From the NRBV perspective, firms can create

strategic value by developing capabilities that enable them to respond to environmental constraints and effectively manage natural resources (Hart, 1995). The findings show that CEP significantly enhances both SCC and SCF, suggesting that circular resource exchanges can stimulate the development of relational and operational capabilities. Specifically, CEP encourages firms to strengthen inter-organizational coordination while also increasing their ability to reconfigure sourcing, production, and resource flows. Thus, this study extends the NRBV by demonstrating that the value of circular resource practices can be realized through capability development across the supply chain, rather than solely through direct resource efficiency outcomes (Bag & Rahman, 2021).

Second, this study advances DCT by identifying SCC and SCF as two complementary mechanisms through which CEP contributes to SCR. While previous studies have recognized collaboration and flexibility as important supply chain capabilities (Bag & Rahman, 2023; Karman et al., 2024), the present findings demonstrate that both capabilities mediate the relationship between CEP and SCR. SCC enables firms to integrate external knowledge, information, and resources through inter-organizational relationships, whereas SCF enables them to reconfigure operational resources and processes in response to changing conditions. These findings therefore clarify how circular practices are translated into resilience outcomes through relational and operational reconfiguration. They also reinforce the DCT perspective that resilience is supported by the continuous adaptation of organizational relationships and operational routines rather than by static resource possession alone.

Third, this study contributes to institutional theory by demonstrating that institutional pressure can condition the extent to which CEP contributes to SCR (Leão & Pereira, 2026; Malik et al., 2022). The significant negative moderating effect indicates that stronger coercive institutional pressure weakens the positive relationship between CEP and SCR. This finding suggests that institutional pressure does not necessarily strengthen the resilience benefits of circular practices (Dai et al., 2021); instead, its effectiveness depends on how such pressure interacts with firms' existing capabilities and resource conditions (Nguyen-Viet et al., 2026). One possible explanation is that stronger coercive pressure may increase compliance requirements and resource demands, thereby reducing the capacity available for firms to translate circular practices into resilience benefits (Sharma & Sharma, 2026). This interpretation is particularly relevant in resource-constrained contexts, where firms may have limited capacity to simultaneously meet institutional requirements and invest in capability development (Boso et al., 2017; Ge & Zhang, 2025). Thus, the findings extend institutional theory by highlighting the moderating role of RP in shaping the relationship between CEP and SCR (Chu et al., 2018).

5.3 Practical implications

The findings suggest that managers should view CEP as both an environmental initiative and a means of developing supply chain capabilities. Since SCC and SCF significantly mediate the relationship between CEP and SCR, managers should focus on converting circular resource practices into stronger collaborative and operational capabilities. First, firms should strengthen relationships with suppliers, customers, and industrial symbiosis partners through long-term resource-sharing arrangements, joint planning, and transparent information exchange. Establishing clear mechanisms for sharing information

about resource availability, quality, timing, and disruptions can improve coordination and facilitate collective responses.

Second, managers should strengthen SCF by reducing excessive dependence on a single source of materials and developing alternative sourcing options, flexible production arrangements, and adaptable logistics plans. Where feasible, digital technologies can be used to improve visibility of resource flows and support faster reallocation of materials and production capacity during disruptions. Importantly, these actions should be aligned with the firm's actual resource capacity rather than pursued as isolated investments in circular technologies.

For SMEs in particular, managers can also consider participating in industrial symbiosis networks or shared platforms to access resources, knowledge, technical expertise, and potential partners that may be difficult to develop independently. Government-supported training, technical assistance, and financing programs may further help firms overcome capability and resource constraints during the transition toward circular practices.

For policymakers, the negative moderating effect of regulatory pressure provides an important implication for policymakers. The finding indicates that stronger coercive institutional pressure weakens the positive relationship between CEP and SCR. This does not imply that environmental regulation should be reduced or abandoned. Rather, it suggests that the design and implementation of regulatory requirements matter for firms' ability to translate circular practices into resilience outcomes.

Policymakers should therefore consider complementing regulatory requirements with enabling instruments that reduce implementation barriers. These may include technical assistance, capability-building programs, access to green finance, tax incentives, and guidance on industrial symbiosis implementation. Such instruments can help firms, particularly resource-constrained SMEs, develop the collaborative and operational capabilities required to implement CEP effectively.

Policymakers should also consider developing shared infrastructure that facilitates industrial resource exchange. Digital platforms for resource matching, standardized information on secondary materials, and mechanisms for knowledge sharing can reduce information barriers and facilitate connections between firms with complementary resource needs. In this way, policy intervention can focus not only on requiring firms to adopt circular practices but also on creating the institutional and infrastructural conditions that enable those practices to generate resilience benefits.

Overall, the findings suggest that the policy challenge is not simply to increase regulatory pressure, but to ensure that regulatory requirements are accompanied by an enabling environment in which firms have sufficient capacity to develop collaboration and flexibility. This approach can help policymakers align environmental objectives with the development of more resilient supply chains.

6. Limitations and future research directions

Although this study provides insights into the key drivers of sustainable supply chain networks, several limitations remain, particularly regarding the cross-sectional nature of the data and the single-country research context. These limitations highlight the need for more systematic and empirically grounded investigations in future research. Rather than merely extending sample sizes or replicating existing models, future studies should further explore the underlying mechanisms of the institutional paradox by identifying the threshold at which regulatory pressure begins to generate unintended negative consequences. Specifically, future research could examine how excessive institutional coercion creates a double burden for firms, potentially encouraging symbolic compliance behaviors rather than substantive sustainability-oriented innovation (To, 2026). Such investigations would contribute to a deeper understanding of the nonlinear effects of institutional pressures on organizational capability development.

A promising research direction is to investigate algorithm-based trust governance mechanisms, particularly the role of smart contracts in addressing information asymmetry, enhancing data security, and overcoming coordination barriers that often limit the effectiveness of spontaneous industrial symbiosis networks. By examining how digital trust mechanisms facilitate inter-organizational resource exchange, future research can provide new insights into the governance foundations of circular supply chain ecosystems.

Furthermore, future studies should move beyond examining only positive outcomes and investigate the potential domino effects and ripple risks associated with highly interconnected industrial symbiosis networks (Fric et al. 2025; Karman et al., 2024). Understanding how disruptions propagate across interdependent networks would provide a more comprehensive perspective on supply chain viability and resilience under complex environmental conditions. Finally, future research should shift from static performance measurement toward capturing the evolution of higher-order dynamic capabilities over time. The application of emerging technologies such as digital twins may offer new opportunities to monitor and simulate supply chain transformations in real time, enabling firms to proactively reconfigure operational routines and partnership structures to absorb environmental and market disruptions more effectively.

Declarations

Funding Declaration:

The authors received no financial support for the research, authorship, and/or publication of this article.

Author Contribution

The contributions of each author to this research are as follows: Ha Kien Tan conceived the research idea and designed the study. All authors collected and analyzed the data. All authors collaborated on the manuscript preparation, contributed to critical revisions, and approved the final version for publication.

Acknowledgement

No

References

1. Agyabeng-Mensah Y, Tang L, Afum E, Baah C, Dacosta E (2021) Organisational identity and circular economy: are inter and intra organisational learning, lean management and zero waste practices worth pursuing? Sustainable Prod Consum 28:648–662. https://doi.org/10.1016/j.spc.2021.06.018
2. Ali MU, Khan I, Khan H (2025) Leveraging industry 4.0 technologies and industrial symbiosis: Advancing circular economy practices in BRICS economies. J Environ Manage 383., Article 125471. https://doi.org/10.1016/j.jenvman.2025.125471
3. Baah C, Agyabeng-Mensah Y, Afum E, Kumi CA (2023) Do circular economy practices accelerate CSR participation of SMEs in a stakeholder-pressured era? A network theory perspective. J Clean Prod 394., Article 136348. https://doi.org/10.1016/j.jclepro.2023.136348
4. Bag S, Dhamija P, Bryde DJ, Singh RK (2022) Effect of eco-innovation on green supply chain management, circular economy capability, and performance of small and medium enterprises. J Bus Res 141:60–72. https://doi.org/10.1016/j.jbusres.2021.12.011
5. Bag S, Gupta S, Foropon C (2019) Examining the role of dynamic remanufacturing capability on supply chain resilience in circular economy. Manag Decis 57(4):863–885. https://doi.org/10.1108/MD-07-2018-0724
6. Bag S, Rahman MS (2023) The role of capabilities in shaping sustainable supply chain flexibility and enhancing circular economy-target performance: an empirical study. Supply Chain Management: Int J 28(1):162–178. https://doi.org/10.1108/SCM-05-2021-0246
7. Becker JM, Ringle CM, Sarstedt M (2018) Estimating moterating effects in PLS-SEM and PLSc-SEM: interaction term gerneration*data treatment. J Appl Struct Equation Model 2:1–21. https://doi.org/10.47263/JASEM.2(2)01
8. Boom-Cárcamo E, Peñabaena-Niebles R (2026) Industrial Symbiosis in Emerging Countries: A Study on Economic, Social and Environmental Business Challenges. Results Eng. Article 109460 https://doi.org/10.1016/j.rineng.2026.109460
9. Boso N, Danso A, Leonidou C, Uddin M, Adeola O, Hultman M (2017) Does financial resource slack drive sustainability expenditure in developing economy small and medium-sized enterprises? J Bus Res 80:247–256. https://doi.org/10.1016/j.jbusres.2017.06.016
10. Bozkurt S, Celik F, Gligor D (2026) Assessing the current state of mediation analysis in marketing research: Pitfalls and recommendations. J Bus Res 206:115934. https://doi.org/10.1016/j.jbusres.2025.115934
11. Brislin RW (1970) Back-translation for cross-cultural research. J Cross-Cult Psychol 1(3):185–216. https://doi.org/10.1177/135910457000100301

12. Castillo A, Rescalvo-Martin E, Karatepe OM (2026) How is common method bias addressed using partial least squares structural equation modeling in hospitality and tourism research? Tourism Rev 81(1):204–228. https://doi.org/10.1108/TR-07-2025-0762
13. Chebbi K, Arfa NB (2025) Greening under pressure: How firms manage waste in times of climate policy uncertainty? The role of green technologies, policies, and carbon emission. J Environ Manage 394:127458. https://doi.org/10.1016/j.jenvman.2025.127458
14. Chen D, Hatani F (2026) Institutional work for green building: capacity development in Hong Kong's construction industry. Asian Bus Manage 1–23. https://doi.org/10.1057/s41291-026-00333-z
15. Chertow MR (2007) Uncovering industrial symbiosis. J Ind Ecol 11(1):11–30. https://doi.org/10.1162/jiec.2007.1110
16. Chu Z, Xu J, Lai F, Collins BJ (2018) Institutional theory and environmental pressures: The moderating effect of market uncertainty on innovation and firm performance. IEEE Trans Eng Manage 65(3):392–403. https://aquila.usm.edu/fac_pubs/15490
17. Cui M, Zhang X, Li J (2026) Revisiting an urban legend: an experimental assessment of common method variance's impact on relationships in self-reported data. J Public Adm Res Theor 36(3):343–360. https://doi.org/10.1093/jopart/muag008
18. Crick JM, Crick D (2025) Designing robust electronic surveys in marketing research. J Strategic Mark 33(5):559–572. https://doi.org/10.1080/0965254X.2025.2468679
19. Dai J, Xie L, Chu Z (2021) Developing sustainable supply chain management: The interplay of institutional pressures and sustainability capabilities. Sustainable Prod Consum 28:254–268. https://doi.org/10.1016/j.spc.2021.04.017
20. Dankyira FK, Essuman D, Boso N, Ataburo H, Quansah E (2024) Clarifying supply chain disruption and operational resilience relationship from a threat-rigidity perspective: evidence from small and medium-sized enterprises. Int J Prod Econ 274., Article 109314. https://doi.org/10.1016/j.ijpe.2024.109314
21. Dubey R, Bryde DJ, Blome C, Dwivedi YK, Childe SJ, Foropon C (2024) Alliances and digital transformation are crucial for benefiting from dynamic supply chain capabilities during times of crisis: A multi-method study. Int J Prod Econ 269:109166. https://doi.org/10.1016/j.ijpe.2024.109166
22. Edwin Cheng TC, Kamble SS, Belhadi A, Ndubisi NO, Lai KH, Kharat MG (2022) Linkages between big data analytics, circular economy, sustainable supply chain flexibility, and sustainable performance in manufacturing firms. Int J Prod Res 60(22):6908–6922. https://doi.org/10.1080/00207543.2021.1906971
23. Ellström D, Holtström J, Berg E, Josefsson C (2021) Dynamic capabilities for digital transformation. J Strategy Manage 15(2):272–286. https://doi.org/10.1108/JSMA-04-2021-0089
24. El Baz J, Ruel S (2021) Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. Int J Prod Econ 233., Article 107972. https://doi.org/10.1016/j.ijpe.2020.107972

25. Filimonau V, Ermolaev VA (2022) Exploring the potential of industrial symbiosis to recover food waste from the foodservice sector in Russia. Sustainable Prod Consum 29:467–478. https://doi.org/10.1016/j.spc.2021.10.028
26. Fric U, Levnajić Z, Modic D, Rončević B (2025) Industrial symbiosis networks supporting circularity: Understanding complexity, cyclicality and resilience. Environ Technol Innov 37., Article 104026. https://doi.org/10.1016/j.eti.2025.104026
27. Ge H, Zhang X (2025) From uncertainty to sustainability: How climate policy uncertainty shapes corporate ESG? Int Rev Econ Finance 98:104011. https://doi.org/10.1016/j.iref.2025.104011
28. Godinho Filho M, Gonella JDSL, Latan H, Ganga GMD (2024) Awareness as a catalyst for sustainable behaviors: A theoretical exploration of planned behavior and value-belief-norms in the circular economy. J Environ Manage 368., Article 122181. https://doi.org/10.1016/j.jenvman.2024.122181
29. Goulder LH, Parry IW (2008) Instrument choice in environmental policy. Rev Environ Econ Policy 2(2):152–174. https://doi.org/10.1093/reep/ren005
30. Hair JF, Hult GTM, Ringle CM, Sarstedt M (2026a) *A primer on partial least squares structural equation modeling (PLS-SEM)* (4th ed.). Sage. ISBN: 978-1071998854
31. Hair JF, Sharma PN, Chin WW, Sarstedt M, Ringle CM (2026b) A multimethod SEM framework for analyzing models with latent variables. J Global Mark 39(2):167–182. https://doi.org/10.1080/08911762.2026.2638909
32. Hart SL (1995) A natural-resource-based view of the firm. Acad Manage Rev 20(4):986–1014. https://doi.org/10.5465/amr.1995.9512280033
33. Jiao J, Liu C, Xu Y, Hao Z (2022) Effects of strategic flexibility and organizational slack on the relationship between green operational practices adoption and firm performance. Corp Soc Responsib Environ Manag 29(3):561–577. https://doi.org/10.1002/csr.2220
34. Karman A, Prokop V, Jabbour deS, A.B.L (2024) Circular economy practices as a shield for the long-term organisational and network resilience during crisis: Insights from an industrial symbiosis. J Clean Prod 466., Article 142822. https://doi.org/10.1016/j.jclepro.2024.142822
35. Kazancoglu I, Ozbiltekin-Pala M, Mangla SK, Kazancoglu Y, Jabeen F (2022) Role of flexibility, agility and responsiveness for sustainable supply chain resilience during COVID-19. J Clean Prod 362., Article 132431. https://doi.org/10.1016/j.jclepro.2022.132431
36. Katsaliaki K, Galetsi P, Kumar S (2022) Supply chain disruptions and resilience: a major review and future research agenda. Ann Oper Res 319(1):965–1002. https://doi.org/10.1007/s10479-020-03912-1
37. Kock N (2015) Common method bias in PLS-SEM: A full collinearity assessment approach. Int J e-Collaboration (IJEC) 11(4):1–10. https://doi.org/10.4018/ijec.2015100101
38. Le TT, Ferraris A, Dhar BK (2023) The contribution of circular economy practices on the resilience of production systems: eco-innovation and cleaner production's mediation role for sustainable development. J Clean Prod 424., Article 138806. https://doi.org/10.1016/j.jclepro.2023.138806

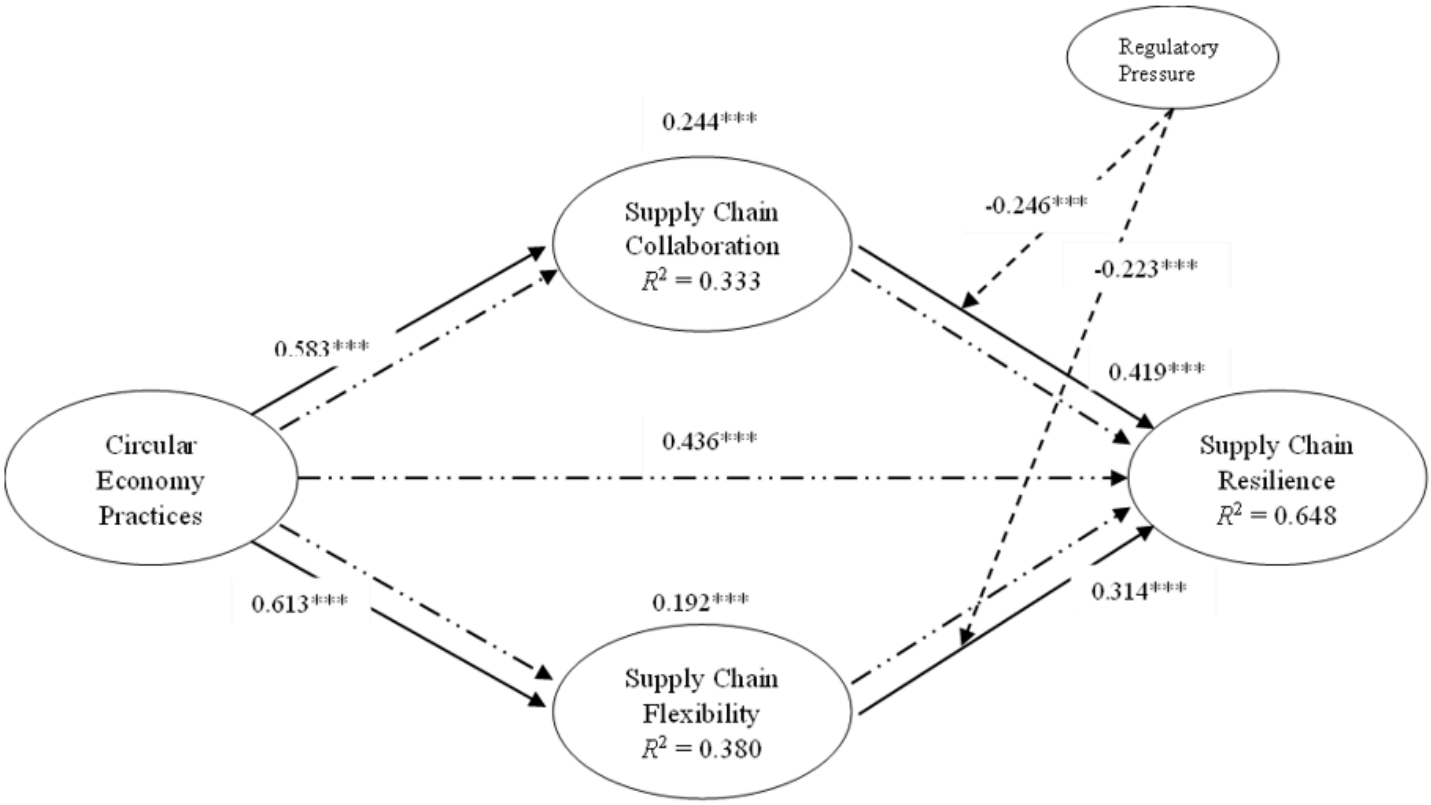
39. Leão J, Pereira LDS (2026) Perspectives from 50 experts on Brazil's supply chain decarbonization and the role of digital tools. Int J Organizational Anal 34(4):1559–1575. https://doi.org/10.1108/IJOA-12-2024-5119
40. Liao SH, Hu DC, Ding LW (2017) Assessing the influence of supply chain collaboration value innovation, supply chain capability and competitive advantage in Taiwan's networking communication industry. Int J Prod Econ 191:143–153. https://doi.org/10.1016/j.ijpe.2017.06.001
41. Malik A, Pereira V, Budhwar P, Froese FJ, Minbaeva D, Sun J, Xue S (2022) Multilevel relational influences on HRM practices: a cross-country comparative reflective review of HRM practices in Asia. Asian Bus Manage 21(5):745–779. https://doi.org/10.1057/s41291-022-00208-z
42. Malinauskienė M, Kliopova I, Hugi C, Staniškis JK (2018) Geostrategic supply risk and economic importance as drivers for implementation of industrial ecology measures in a nitrogen fertilizer production company. J Ind Ecol 22(2):422–433. https://doi.org/10.1111/jiec.12561
43. Marsh AT, Hafez H, Drewniok MP (2026) Element-based material flow analysis to identify unexplored industrial symbiosis opportunities. Sustainable Prod Consum 66:181–193. https://doi.org/10.1016/j.spc.2026.05.011
44. Memon MA, Thurasamy R, Cheah JH, Ting H, Kreienbaum C, Ringle CM (2026) Moderated mediation analysis using SmartPLS: a tutorial for business researchers. J Appl Struct Equation Model 10(1):1–28. https://doi.org/10.47263/JASEM.10(1)01
45. Mensah PO, Yong JY, Dura CC, Mensah HK (2025) Institutional networking capability as a catalyst for sustainable supply chains in the manufacturing sector of Ghana: The role of green human resource management strategy and green dynamic capability. J Environ Manage 387:125865. https://doi.org/10.1016/j.jenvman.2025.125865
46. Meyer JW, Rowan B (1977) Institutionalized organizations: Formal structure as myth and ceremony. Am J Sociol 83(2):340–363. https://doi.org/10.1086/226550
47. Mubarik MS, Gunasekaran A, Khan SA, Mubarak MF (2025) Decarbonization through supply chain innovation: Role of supply chain collaboration and mapping. J Clean Prod 507., Article 145492. https://doi.org/10.1016/j.jclepro.2025.145492
48. Nguyen-Viet B, Chi-Luong L, Nguyen-Khanh N (2026) Green AI adoption for circular and agile supply chains: ESG-driven pathways in Vietnam's emerging technological economy. Int J Productivity Perform Manage 1–20. https://doi.org/10.1108/IJPPM-10-2025-1072
49. Ozbekler TM, Ozturkoglu Y (2020) Analysing the importance of sustainability-oriented service quality in competition environment. Bus Strategy Environ 29(3):1504–1516. https://doi.org/10.1002/bse.2449
50. Patwa N, Sivarajah U, Seetharaman A, Sarkar S, Maiti K, Hingorani K (2021) Towards a circular economy: An emerging economies context. J Bus Res 122:725–735. https://doi.org/10.1016/j.jbusres.2020.05.015
51. Podsakoff PM, Podsakoff NP, Williams LJ, Huang C, Yang J (2024) Common method bias: It's bad, it's complex, it's widespread, and it's not easy to fix. *Annual Review of Organizational Psychology and*

Organizational Behavior, *11*(2024), 17–61. https://doi.org/10.1146/annurev-orgpsych-110721-040030

52. Ponomarov SY, Holcomb MC (2009) Understanding the concept of supply chain resilience. Int J Logistics Manage 20(1):124–143. https://doi.org/10.1108/09574090910954873
53. Roemer E, Schuberth F, Henseler J (2021) HTMT2–an improved criterion for assessing discriminant validity in structural equation modeling. Industrial Manage Data Syst 121(12):2637–2650. https://doi.org/10.1108/IMDS-02-2021-0082
54. Rodríguez-González RM, Maldonado-Guzmán G, Madrid-Guijarro A, Garza-Reyes JA (2022) Does circular economy affect financial performance? The mediating role of sustainable supply chain management in the automotive industry. J Clean Prod 379:134670. https://doi.org/10.1016/j.jclepro.2022.134670
55. Rousselière S, Coisnon T, Hassan M, Musson A, Rousselière D (2024) Beyond Porter hypothesis: Empirical evidence of heterogeneous and contextual economic returns of eco-innovations on a sample of European SMEs. J Clean Prod 484., Article 144329. https://doi.org/10.1016/j.jclepro.2024.144329
56. Sharma M, Luthra S, Joshi S, Kumar A, Jain A (2023) Green logistics driven circular practices adoption in industry 4.0 Era: A moderating effect of institution pressure and supply chain flexibility. J Clean Prod 383., Article 135284. https://doi.org/10.1016/j.jclepro.2022.135284
57. Sharma V, Sharma M (2026) MSME sustainable performance in India's circular economy: Networks, innovation, and institutional enablers. J Clean Prod 546., Article 147745. https://doi.org/10.1016/j.jclepro.2026.147745
58. Söderlund M (2023) Moderator variables in consumer research: A call for caution. J Retailing Consumer Serv 73:103352. https://doi.org/10.1016/j.jretconser.2023.103352
59. Sudusinghe JI, Seuring S (2022) Supply chain collaboration and sustainability performance in circular economy: A systematic literature review. Int J Prod Econ 245:108402. https://doi.org/10.1016/j.ijpe.2021.108402
60. Tang X, He Y, Salling M (2021) Optimal pricing and production strategies for two manufacturers with industrial symbiosis. Int J Prod Econ 235., Article 108084. https://doi.org/10.1016/j.ijpe.2021.108084
61. Teece DJ, Pisano G, Shuen A (1997) Dynamic capabilities and strategic management. Strateg Manag J 18(7):509–533. https://doi.org/10.1002/(SICI)1097-0266)18:7%3C509::AID-SMJ882%3E3.0.CO;2-Z
62. To LMT (2026) From significance to substance: making moderation meaningful in marketing research. Italian J Mark 2026(1):15. https://doi.org/10.1007/s43039-026-00140-6
63. Wang L, Zhang Q, Wang H (2022) Effect of policy on industrial symbiosis: Simulation study from the perspective of enterprise operation. Sustainable Prod Consum 30:962–972. https://doi.org/10.1016/j.spc.2022.01.014

64. Wang S, Cheah JH, Wong CY, Ramayah T (2024) Progress in partial least squares structural equation modeling use in logistics and supply chain management in the last decade: a structured literature review. Int J Phys Distribution Logistics Manage 54(7–8):673–704. https://doi.org/10.1108/IJPDLM-06-2023-0200
65. Yao Y, Fabbe-Costes N (2018) Can you measure resilience if you are unable to define it? The analysis of Supply Network Resilience (SNRES*). Supply Chain Forum*. Int J 19(4):255–265. https://doi.org/10.1080/16258312.2018.1540248
66. Yazan DM, Fraccascia L (2020) Sustainable operations of industrial symbiosis: an enterprise input-output model integrated by agent-based simulation. Int J Prod Res 58(2):392–414. https://doi.org/10.1080/00207543.2019.1590660
67. Yu W, Jacobs MA, Chavez R, Yang J (2019) Dynamism, disruption orientation, and resilience in the supply chain and the impacts on financial performance: a dynamic capabilities perspective. Int J Prod Econ 218:352–362. https://doi.org/10.1016/j.ijpe.2019.07.013
68. Zhao X, Lynch JG Jr., Chen Q (2010) Reconsidering Baron and Kenny: Myths and truths about mediation analysis. J Consum Res 37(2):197–206. https://doi.org/10.1086/651257
69. Zhu Q, Sarkis J, Lai KH (2012) Examining the effects of green supply chain management practices and their mediations on performance improvements. Int J Prod Res 50(5):1377–1394. https://doi.org/10.1080/00207543.2011.571937

Figures



Note: ***$p < 0.001$ (two-tailed test)
Direct effect
Indirect effect
Moderating effect
Figure 1. Structural model results
Source: Authors' own work

Figure 1

See image above for figure legend