Research Article

Construct Validity of Circular Economy Practices, Total Quality Management, Green Supply Chain Management, and Firm Performance: An Absorptive Capacity Perspective by First-Order Confirmatory Factor Analysis

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Udomsak Chomsuk[1]
Piyachat Burawat[2]
Sungworn Ngudgratoke[3]

Abstract

The purpose of this study was to explore and validate the construct factors of sustainability management, which is a critical priority for firms and widely accepted as a key mechanism for improving environmental responsibility and waste management practices, especially from the perspective of absorptive capacity theory. The purpose was to determine the main factors that are linked to circular economy practices (CEP), total quality management (TQM), green supply chain management (GSCM) and firm performance (FP). The survey was conducted among 847 respondents from different industrial sectors including paint and construction materials, food and personal care, flexible and rigid packaging and chemical products. First, exploratory factor analysis (EFA) was conducted using IBM SPSS to identify and refine the underlying factor structure of the data. Subsequently, a first-order measurement model was analyzed using Mplus to confirm the factor structure through confirmatory factor analysis (CFA). All retained indicators exhibited factor loadings greater than 0.60 in the EFA, indicating satisfactory associations between the observed indicators and their respective factors. The CFA results demonstrated an acceptable overall model fit (χ^2 = 134.266, χ^2/df = 3.530, CFI = 0.978, RMSEA = 0.041, $p < 0.050$).

[1] Ph.D. Student, Faculty of Business Administration, Rajamangala University of Technology Thanyaburi, Thailand
E-mail: udomsak_c@mail.rmutt.ac.th

[2] Faculty of Business Administration, Rajamangala University of Technology Thanyaburi, Thailand
E-mail: piyachat_b@rmutt.ac.th

[3] School of Education, Sukhothai Thammathirat Open University, Thailand
E-mail: sungworn.ngu@stou.ac.th

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In addition, the constructs demonstrated satisfactory internal consistency, with composite reliability (CR) values ranging from 0.77 to 0.89 and Cronbach's alpha coefficients ranging from 0.935 to 0.962.

Keywords: *Absorptive Capacity Theory, Circular Economy Practices, Sustainability Management*

Introduction

This study investigates the constructs of circular economy practices (CEP), total quality management (TQM), green supply chain management (GSCM), and firm performance (FP) in Thailand's palm oil-based industrial sectors. Thailand is one of the world's major palm oil producers, providing essential feedstocks and derivatives for a wide range of downstream applications, including food, pharmaceuticals, personal care and cosmetics, construction materials, biopolymers, and rigid and flexible packaging. To understand organizational perspectives on sustainability-oriented management systems, this study adopts the absorptive capacity (ACAP) perspective lens as a theoretical lens for interpreting the conceptual relationships among CEP, TQM, GSCM, and FP. Absorptive capacity describes an organization's ability to recognize valuable external knowledge, assimilate and transform that knowledge, and apply it to organizational activities. Within this perspective, CEP can be viewed as representing sustainability-related knowledge and practices that organizations seek to recognize and incorporate into their operations. TQM reflects internal managerial routines through which knowledge can be assimilated, standardized, and continuously improved, whereas GSCM reflects the integration and application of environmental knowledge across organizational and supply chain boundaries. FP represents the organizational outcomes associated with the effective deployment of these management practices and capabilities. Thus, ACAP provides a theoretical foundation for viewing CEP, TQM, GSCM, and FP as distinct but conceptually related components of an integrated sustainability management system. In this study, ACAP serves as an interpretive theoretical framework rather than as a separately measured latent construct.

The study focuses on top and middle managers, who are responsible for strategic decision-making and operational supervision. The multidimensional character of these constructs makes factor analysis a robust methodological tool for exploration of fundamental structures and measurement quality. The initial analytical step involved exploratory factor analysis (EFA), which provides a systematic approach for identifying underlying factor structures. Extraction, retention, and rotation methods were determined based on criteria such as eigenvalues, factor loadings, and theoretical interpretability. Although EFA offers a high degree of methodological flexibility, its results depend heavily on the informed judgment of the researcher (Sürücü et al., 2022).

The hypothesized measurement model was tested and validated through confirmatory factor analysis (CFA). CFA is a theory-driven technique that evaluates the extent to which observed indicators represent their underlying latent constructs and facilitates the assessment of dimensionality, reliability, and both convergent and discriminant validity. The model was tested using standard fit indices (χ^2, χ^2/df, CFI, TLI, RMSEA and SRMR) in Mplus. Sample size is critical to the performance of CFA and SEM. Sriutaisuk et al. (2025) provide evidence that smaller samples tend to converge less often and are more likely to experience missing data, especially when binary (C = 2) or polytomous (C = 5) scales are used. McNeish (2020) argued that although larger sample sizes typically help models converge, they can lead to more Heywood cases such as negative error variances. These results highlight the need for determining an optimal sample size when applying EFA and CFA results in the context of structural equation modeling. The minimum sample size for this study was determined using by structural equation model sample size calculator software developed by Dr. Daniel Soper (2026), Professor of information systems & decision sciences of California State University in United States.

Literature review

At the moment, the Thai government has been promoting national ESG policies for reducing pollution, saving bio-based and virgin materials, and improving environmental responsibility. The policies are a response to growing concerns about resource depletion, price volatility and non-tariff trade barriers, in particular in sectors such as non-metallic minerals, biomass, fossil-based energy carriers and metallic minerals. This has been exacerbated by the long-standing dominance of the linear economy based on finite resources and unsustainable production–consumption patterns. Hence, previous works emphasize the need to shift towards circular economy (CE) models for the reduction of environmental degradation, enhancement of resource efficiency and augmentation of national competitiveness (Agyabeng-Mensah et al., 2021; Demir et al., 2019). This scarcity and instability in the market is exacerbated by external factors such as population growth and increased consumption (Wu & Li, 2022; Zhang et al., 2021). In an economy based on linearity activities such as deforestation, waste generation and loss of biodiversity are not linked to resource recovery and value creation (Thorley et al., 2021; Uggetti et al., 2018). International policy agendas are increasingly promoting CE principles such as reduction, reuse and recycling supported by environmental management frameworks such as ISO 14001 (Jacob-John et al., 2021). In Eastern and South-Eastern Asia, trends in material consumption suggest the need for circularity in response to the increased environmental pressures resulting from infrastructure expansion and the relocation of resource-intensive industries (Alexandru et al., 2020). Empirical evidence shows that CE practices

reduce the use of raw materials, lower operating costs and increase the competitiveness of the firm, while delivering environmental benefits through emissions reduction and conservation of resources (Agyabeng-Mensah et al., 2021; MacArthur, 2013; Planing, 2015).

The effectiveness of CE delivery, however, depends on strong organizational capabilities. Total Quality Management enhances process integration and performance in circular systems (Marín-Vinuesa et al., 2023), and absorptive capacity theory accounts for how firms internalize sustainability knowledge (Cohen & Levinthal, 1990; Stocco et al., 2022; Zahra & George, 2002). Although ISO 14001 offers an important institutional framework, sustainability outcomes are also determined by leadership, culture, and stakeholder pressures. Hence it is necessary to interpret and examine the strength of the framework carefully (Psomas et al., 2011; Sharma & Modgil, 2020; Militaru & Zanfir, 2016).



Figure 1 Development of phenomenon dynamics in this case study based on absorptive capacity theory (ACAP)

Source: Cohen and Levinthal (1990)

1. Circular economy practice

Regulatory and standardization requirements represent important external pressures in circular-economy implementation. Environmental requirements can encourage firms to formalize operational systems while complying with increasingly stringent environmental regulations. Standardization can facilitate coordination, particularly in firms with complex supply chains (Khajuria et al., 2022), while environmental compliance is associated with long-term corporate sustainability and legitimacy (Planing, 2015). Circular-economy implementation may also be constrained by capital requirements and technological limitations. High investment requirements

and limited technological capabilities can restrict the adoption of advanced sustainability practices (Delmas & Toffel, 2008). From a dynamic-capability perspective, investment capacity and technological readiness influence the ability of firms to respond to changing environmental requirements. Economic inducements, including financial incentives, cost savings, and anticipated economic benefits, may further motivate firms to adopt circular and environmentally oriented practices (Thorley et al., 2021).

2. Total quality management

The findings support Deming's (1986) assertion that customer satisfaction is a direct result of internal processes that are well managed. Customer focus and process management are empirically integrated dimensions, rather than separate practices (Chomsuk & Saraphat, 2019). In TQM oriented organizations, the customer requirements are translated into process standards through continuous feedback mechanisms. Theoretically, this grouping is also coherent because process control systems incorporate the "voice of the customer," as proposed by Sharma and Modgil (2020). Accordingly, the construct customer-oriented process management (COPM) represents the strategic and operational alignment between customer expectations and internal quality management routines. Product design is a different but necessary TQM dimension. As consumer demand for green and sustainable products has increased, so has the profile of design quality as a proactive element of quality management. The quality framework of Garvin (1987) emphasizes the role of design quality in conformance, reliability and durability during the product life cycle. Design is sometimes associated with innovation but in TQM it has a particular role that it imbeds quality principles at the initial stages of development. The independent development of this construct indicates that firms view design not merely as a technical activity, but also as a quality mechanism of strategy to affect downstream performance (Banihashemi et al., 2019).

3. Green supply chain management

GSCM is the integration of internal environmental activities with external supply-chain collaboration. Prior research identifies internal environmental management and green purchasing as core GSCM practices that embed environmental considerations into organizational policies, procurement, routines, and resource allocation (Agyabeng-Mensah et al., 2021). Green design and investment recovery also support resource efficiency through product and process innovation, reuse, recycling, and recovery activities (Stocco et al., 2022). In addition, supplier integration extends environmental management beyond organizational boundaries through shared environmental objectives, collaborative design, and supplier participation in environmental initiatives (Sharma &

Modgil, 2020). These strands of prior research provide a theoretical basis for examining the dimensional structure of GSCM in the present industrial context.

4. Firm performance

The firm's performance was multidimensional, including reputational, operational and environmental outcomes. Reputation for sustainability: The first dimension is defined by high loadings on social responsibility, brand credibility and environmental engagement indicators. This construct refers to stakeholders' perceptions of a company's commitment and is consistent with the stakeholder theory that emphasizes the importance of the expectations from different stakeholder groups (Freeman & Phillips, 1984). The high visibility of brand and societal indicators support the view that branding and accountability with a sustainability orientation enhance corporate legitimacy (Delmas, 2001). This dimension is further corroborated by the institutional theory, in which firms are expected to adopt the norms and expectations of sustainability in society to maintain their legitimacy and competitive positioning (DiMaggio & Powell, 1983). The second dimension, business efficiency, is affected by factors relating to economic performance, operational efficiency and resource optimization. This cluster illustrates an instrumental perspective on sustainability, where environmental and quality practices are valued for their contribution to economic outcomes.

This result is consistent with the resource-based view (RBV) that considers efficiency-enhancing capabilities as sources of competitive advantage (Barney, 1991). Previous studies additionally suggest the joint positive effect of green and lean practices on environmental and economic performance (Marín-Vinuesa et al., 2023). The third dimension is Environmental performance that includes reduction of emissions, minimization of waste, conservation of resources and compliance with regulation. This construct is also in line with the natural resource-based view (NRBV) that considers environmental capabilities as strategic assets (Hart, 1995). Strong environmental performance also facilitates legitimacy-building mechanisms, as firms demonstrate conformity to regulatory frameworks (e.g., ISO 14001) and broader societal expectations (Suchman, 1995).

Findings finally conclude regarding a complex framework of firm performance in relation to sustainability that have illustrated in the filed as fours dimension as follows economy practices, total quality management, green supply chain management and measure by firm performance. Despite external legitimacy and stakeholder alignment are operationalized as constructs such as keeping reputations and economic performance. Internal operational efficiency is operationalized as business

efficiency. The concept of business efficiency sounds good but needs to be proven. Collectively, these constructs reinforce the idea that sustainability is not a single monolithic concept, but rather has reputational, operational, and environmental dimensions. These findings are in line with theoretical frameworks like Stakeholder Theory, RBV, NRBV and Legitimacy Theory which offer a robust lens to interpret and further validate the constructs. (Delmas, 2001).

Research methodology

The questionnaire employed a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Content validity was assessed by four experts using the Index of Item–Objective Congruence (IOC), with values exceeding the acceptable threshold of 0.50.

The study population comprised 11,586 firms operating in key Thai industrial sectors, including chemicals, food, pharmaceuticals, personal care and cosmetics, construction materials, biopolymers, and rigid and flexible packaging, of which 1,452 firms held ISO 14001 certification (Department of Business Development, 2023; Thai Industrial Standards Institute, 2023). Eligible participants were top- and middle-level managers with direct knowledge of their firm’s environmental and operational management practices. A purposive approach was adopted to identify eligible managerial respondents, while convenience sampling was used to distribute questionnaires through direct contact and email.

The minimum sample size was calculated using the structural equation model sample size calculator developed by Dr. Daniel Soper (2026), which recommended a minimum of 207 respondents. Of the 2,500 questionnaires distributed, 847 valid responses were obtained, yielding a valid response rate of 33.88%. As one eligible respondent represented each participating firm, the final sample comprised 847 respondents from 847 individual firms, exceeding the estimated minimum sample size, as presented in Table 1.

To ensure independence between exploratory and confirmatory analyses, the dataset was randomly divided into two mutually exclusive subsamples. The first subsample (n = 536) was allocated to EFA to identify and refine the underlying factor structure, whereas the second subsample (n = 311) was reserved for CFA to independently evaluate the measurement model derived from EFA. Both subsamples exceeded the estimated minimum sample size of 207 observations. This split-sample approach reduced the risk of capitalization on chance and strengthened the methodological rigor of the measurement validation process.

Table 1 The results of structural equation model sample size calculator

Parameter	Number
Expected effect size	0.3
Latent variables	4
Observed variables	20
p-value	0.050
Statistical power	0.95
Recommended minimum sample size	207

Source: Soper (2026)

This study employed a quantitative research design using a cross-sectional survey to examine the relationships among 20 observed variables across four constructs: circular economy practices (CEP: 1. standardization system, 2. compliance with environmental laws, 3. economic inducements, 4. high capital investment cost, 5. technological limitations), total quality management (TQM: 1. customer focus, 2. top management commitment, 3. process management, 4. continuous improvement, 5. product design), green supply chain management (GSCM: 1. green purchasing, 2. green internal integration, 3. green supplier integration, 4. green design, 5. investment recovery), and firm performance (FP: 1. economic performance, 2. environmental performance, 3. operational performance, 4. social performance, 5. brand image).

Exploratory Factor Analysis was conducted using Principal Component Analysis with Varimax rotation by IBM SPSS to examine the underlying factor structure of CEP, TQM, GSCM, and FP. Sampling adequacy was assessed using the Kaiser-Meyer Olkin (KMO) measure with value gather than 0.800 considered indicative of adequate sampling suitability. Items with factor loadings greater than were considered acceptable for retention (Sürücü et al., 2022).

Subsequently, first-order CFA was performed using Mplus to evaluate the measurement model. Standardized factor loadings greater than 0.60, Composite Reliability (CR) greater than 0.700, and Average Variance Extracted (AVE) greater than 0.500 were adopted as the acceptance criteria for convergent validity. Discriminant validity was assessed by comparing the square root of AVE for each construct with its inter-construct correlations. Model fit was evaluated using the following established criteria: RMSEA < 0.080, and CFI > 0.90 (McNeish, 2020).

Research results

The demographic and organizational characteristics of the respondents were examined to provide an overview of the sample. Table 2 presents the distribution of the 847 respondents according to company type, ISO 14001 certification status, gender, age, management level, and firm size. These characteristics provide a descriptive profile of the participating managers and their respective firms.

Table 2 Participants described quantitative research

Characteristics	Company type		ISO14001	
	Nationality	Local	Adoption	Non
Total participants	197	253	201	196
Gender				
Male	121	189	123	98
Female	73	64	77	96
No specification	3	-	1	2
Age				
25-30 Y	1	-	1	-
31-40 Y	11	4	29	9
41-50 Y	89	159	44	65
51-60 Y	82	82	120	119
61 up Y	14	8	7	3
Managing level				
Top-level management	44	89	63	67
Middle-level management	153	164	138	129
Firm size				
≤ 50 million THB	8	166	35	173
> 50 – 200 million THB	123	53	121	23
> 200 million THB	66	34	45	-

As shown in Table 3, the EFA results based on the exploratory sample (n = 536) demonstrated adequate factorability across all four constructs, with KMO values ranging from 0.806 to 0.847 and statistically significant Bartlett's tests ($p < 0.050$). Factor loadings ranged from 0.621 to 0.900, while the total variance explained ranged from 80.79% to 85.68%. Based on these findings, the measurement dimensions were consolidated and relabeled to reflect the identified factor structures and the conceptual relevance of their associated questionnaire items, as presented in

Table 5. The questionnaire was subsequently revised in accordance with the refined measurement structure and administered to a new, independent sample of 311 respondents. First-order CFA was then conducted using Mplus to evaluate the revised measurement model, including construct reliability, convergent validity, discriminant validity, and overall model fit.

Tabel 3 Summary of EFA results and factor adequacy measures

Construct	KMO	Bartlett's test	Factors retained	Factor loading rang	Variance explained
CEP	0.806	p < 0.050	3	0.634 - 0.819	82.11 %
TQM	0.847	p < 0.050	2	0.621 - 0.857	85.68 %
GSCM	0.820	p < 0.050	3	0.702 - 0.895	82.96 %
FP	0.818	p < 0.050	3	0.674 - 0.900	80.79 %

Prior to CFA, Pearson's correlation analysis was conducted using the independent confirmatory subsample (n = 311) to examine the relationships among the 11 study dimensions. As presented in Table 4, the correlation coefficients ranged from 0.347 to 0.864, indicating positive associations of varying magnitudes among the dimensions. These findings provided preliminary information on the interrelationships among the study dimensions. Subsequently, CFA was conducted using the same confirmatory subsample (n = 311) to assess the measurement model, including construct reliability, convergent validity, discriminant validity, and overall model fit.

Table 4 Correlation reports

	1	2	3	4	5	6	7	8	9	10	11	$\overline{X}$	S.D.
ENIND	1											4.18	0.758
INVTECH	0.563	1										3.82	0.817
CUSO	0.520	0.648	1									3.66	0.756
PD	0.347	0.609	0.647	1								3.60	0.801
GREENIN	0.785	0.358	0.473	0.43	1							4.39	0.724
GREENSUP	0.836	0.476	0.498	0.413	0.816	1						4.17	0.745
ECOEFF	0.675	0.458	0.701	0.509	0.646	0.745	1					3.80	0.763
ECOPER	0.555	0.556	0.65	0.537	0.612	0.625	0.695	1				3.88	0.682
SUSRE	0.564	0.544	0.582	0.533	0.509	0.563	0.607	0.713	1			3.76	0.749
BE	0.726	0.459	0.61	0.491	0.662	0.741	0.864	0.675	0.690	1		3.79	0.75
ReCh	0.392	0.359	0.592	0.465	0.568	0.575	0.696	0.758	0.736	0.685	1	3.80	0.705

Note: Correlation is significant at the 0.05 level (2-tailed), n = 311

Table 5 Empirical refinement and relabeling of measurement dimensions based on EFA

Construct	Original dimensions	Coding	Justification for relabeling
CEP	Standardization system + Compliance with environmental laws	Regulatory challenges **(ReCh)**	Regulatory challenges arise from the need for firms to standardize their operational processes while continuously adapting to increasingly stringent environmental requirements and regulations.
	High capital investment cost + Technological limitations	Investment and technology constraints **(INVTECH)**	Both dimensions represent resource- and capability-related barriers to implementing circular-economy practices. Their conceptual similarity supports interpretation as a common constraint-related factor.
	Economic inducements	Economic inducements **(ENIND)**	Economic incentives, financial benefits, and cost-related motivations represent a conceptually distinct mechanism from regulatory requirements and investment/technology constraints and therefore remain a separate factor.
TQM	Customer focus + Process management + Top management commitment + Continuous improvement	Customer-oriented process management **(CUSO)**	Customer requirements were integrated with internal process standards, monitoring, and continuous feedback. EFA indicated that customer orientation and process control were not clearly distinct. Therefore, the final CFA model retained Customer-Oriented Process Management and Product Design as the principal TQM dimensions.
	Product design	Product design **(PD)**	Product design represents a distinct quality-management activity occurring at the product-development stage and therefore remains empirically and conceptually distinguishable from customer/process management.

Table 5 Empirical refinement and relabeling of measurement dimensions based on EFA (cont.)

Construct	Original dimensions	Coding	Justification for relabeling
GSCM	Green purchasing + Green internal integration	Green internal operations **(GREENIN)**	Both sets of indicators describe the integration of environmental considerations into internal purchasing, routines, policies, and resource allocation. Their common organizational orientation supports their consolidation.
	Green supplier integration	Green supply chain collaboration **(GREENSUP)**	Supplier-integration indicators reflect inter-organizational cooperation, shared environmental objectives, and supplier participation in environmental initiatives, distinguishing this factor from internal green operations.
	Green design + Investment recovery	Eco-efficient innovation **(ECOEFF)**	Both dimensions emphasize reducing environmental impacts while recovering or creating economic value through product/process design, reuse, recycling, and resource recovery. Therefore, the common label reflects both environmental and economic efficiency.
FP	Economic performance + Operational performance	Business efficiency **(BE)**	Both dimensions capture the ability of the firm to convert organizational resources and practices into operational and economic outcomes, such as efficiency, productivity, and resource optimization.
	Social performance + Brand image	Sustainability reputation **(SUSRE)**	Both groups of indicators reflect stakeholder perceptions of the firm's sustainability commitment, corporate responsibility, credibility, and reputation. Their common external-facing characteristics support their integration.
	Environmental performance	Environmental performance **(ECOPER)**	Indicators concerning emissions, waste, resource conservation, and environmental compliance represent a specific environmental outcome domain and therefore remain distinct from business efficiency and reputational outcomes.

Following the refinement of the measurement dimensions through EFA, a first-order CFA was conducted using Mplus with the independent confirmatory subsample (n = 311) to evaluate the measurement model. The model demonstrated acceptable fit, with χ^2 = 134.266, χ^2/df = 3.530, CFI = 0.978, and RMSEA = 0.041. Although the chi-square test was statistically significant ($p < 0.050$), the approximate fit indices supported the adequacy of the measurement model. As presented in Table 6, standardized factor loadings ranged from 0.733 to 0.904, composite reliability (CR) values ranged from 0.77 to 0.89, and average variance extracted (AVE) values ranged from 0.62 to 0.73, indicating acceptable convergent validity. Cronbach's alpha coefficients ranged from 0.935 to 0.962, indicating high internal consistency.

Table 6 Confirmation factor analysis reports

Model	Variable	Factor loading	CR	AVE	Discriminant validity	Cronbach's alpha
CE	ENIND	0.739	0.86	0.68	0.825	0.955
	INVTECH	0.854				
	ReCh	0.872				
TQM	CUSO	0.842	0.77	0.62	0.787	0.962
	PD	0.733				
GSCM	GREENIN	0.904	0.89	0.73	0.854	0.945
	GREENSUP	0.873				
	ECOEFF	0.789				
FP	ECOPER	0.868	0.87	0.68	0.825	0.935
	SUSRE	0.784				
	BE	0.821				

Discussion

The full measurement model exhibited greater complexity than the single-construct CFA because multiple latent constructs, inter-construct correlations, and measurement errors were estimated simultaneously. Such complexity may increase the likelihood of model misspecification, multicollinearity, discriminant validity concerns, and residual variance problems (Kolenikov & Bollen, 2012). Model adequacy was therefore evaluated using multiple fit indices, including RMSEA, and CFI, which provide complementary information on overall model fit (McNeish, 2020). At the construct level, all retained indicators showed standardized factor loadings above 0.60, with acceptable CR, AVE, and Cronbach's alpha values. The EFA results further indicated that several originally specified

dimensions were consolidated into broader factors. For CEP, standardization system and compliance with environmental laws were combined into regulatory challenges because of their complete correlation in the present sample, consistent with literature describing standardization and environmental compliance as related institutional pressures (Khajuria et al., 2022). For TQM, customer focus, process management, top management commitment, and continuous improvement were grouped into customer-Oriented process management, while product design remained distinct, broadly consistent with TQM literature (Chomsuk & Saraphat, 2019; Deming, 1986). The refined GSCM and FP dimensions were likewise conceptually consistent with prior studies on internal environmental practices, supply-chain collaboration, resource-based capabilities, stakeholder perspectives, and environmental performance (Sharma & Modgil, 2020; Stocco et al., 2022).

Overall, the CFA results indicated acceptable measurement properties for the refined structure within the present sample, with satisfactory factor loadings, reliability, and convergent validity (Gerbing & Anderson, 1992). However, because the same 847 responses were used for EFA, dimension refinement, and CFA, the analysis does not constitute an independent cross-validation. Accordingly, the findings should be interpreted as evidence of measurement adequacy within this dataset, and future studies should replicate the refined structure using an independent sample.

Theoretical implications

This study contributes to sustainability management literature by providing empirical support for the measurement structures of CEP, TQM, GSCM, and FP. The EFA and first-order CFA results indicate that these constructs are multidimensional and can be represented through a more parsimonious measurement structure, providing a basis for future sustainability-oriented SEM research (Banihashemi et al., 2019). ACAP provides an interpretive lens for understanding the conceptual relationships among the four constructs. ACAP refers to an organization’s ability to recognize, assimilate, transform, and exploit external knowledge (Cohen & Levinthal, 1990; Zahra & George, 2002). Within this perspective, CEP represents sustainability-related knowledge and practices, TQM reflects internal routines for assimilating and improving such knowledge, GSCM represents its application across supply-chain activities, and FP reflects related organizational outcomes. Environmental management routines such as documentation, audits, standardized procedures, and continuous improvement may also support the assimilation and application of sustainability-related knowledge (Sharma & Modgil, 2020).

However, ACAP was used only as an interpretive theoretical lens and was not directly measured. Therefore, the findings should not be interpreted as an empirical test of absorptive capacity. Overall, the study provides an empirically supported measurement framework that can support future research examining structural relationships among CEP, TQM, GSCM, FP, and absorptive capacity.

Practical implications

The refined measurement framework offers practical value for organizations seeking to strengthen sustainability management. The dimensions of CEP, TQM, GSCM, and FP can be used to identify organizational strengths, resource constraints, and priority areas for improvement. In particular, the distinction among regulatory challenges, investment and technology constraints, and economic inducements may help managers differentiate regulatory, resource, and economic barriers to circular-economy implementation. Similarly, customer-oriented process management and product design provide distinct TQM-related areas for managerial attention, while green internal operations, green supply chain collaboration, and eco-efficient innovation represent key domains of GSCM.

Environmental management routines such as standardized reporting, audits, corrective actions, and documented procedures may also support the absorption and application of sustainability-related knowledge (Sharma & Modgil, 2020). However, these practices should not be interpreted as evidence of a causal effect of ISO 14001 certification on absorptive capacity or organizational performance. The framework may also assist policymakers and industry associations in designing targeted support related to regulatory compliance, technological capability, financial resources, process improvement, and supply-chain collaboration.

Limitations and suggestions for future research

Despite the methodological rigor of this study, several limitations should be acknowledged. First, although independent samples were employed for EFA (n = 536) and CFA (n = 311), the use of purposive and convenience sampling may limit the generalizability of the findings. Future research should employ probability-based sampling and replicate the refined measurement framework across different organizational contexts. Second, the study focused on selected industrial sectors in Thailand; therefore, the findings may not be fully generalizable to other industries or countries with different regulatory and sustainability environments. Third, cross-sectional research design and potential differences in data collection periods may introduce temporal bias, as changes in economic conditions, environmental regulations, and sustainability policies could influence respondents'

perceptions and organizational practices. Future studies should consider longitudinal designs and standardized data collection periods to assess the temporal stability of the measurement structure. Finally, reliance on self-reported data from a single managerial respondent per firm may introduce common method bias. Future research should incorporate multiple respondents and objective organizational performance indicators to strengthen the robustness and external validity of the findings.

Conclusion

This study develops an empirically supported measurement framework for CEP, TQM, GSCM, and FP. The initial structure was refined through EFA and evaluated using first-order CFA, with acceptable factor loadings, reliability, convergent validity, discriminant validity, and overall model fit. The refined structure represents CEP through regulatory challenges, investment and technology constraints, and economic inducements; TQM through customer-oriented process management and product design; GSCM through green internal operations, green supply chain collaboration, and eco-efficient innovation; and FP through business efficiency, sustainability reputation, and environmental performance.

From an absorptive capacity perspective, the framework provides a theoretical basis for understanding how sustainability-related knowledge may be recognized, assimilated, transformed, and applied across organizational practices (Cohen & Levinthal, 1990; Zahra & George, 2002). However, because ACAP was not directly measured, the findings should be interpreted as theoretically consistent with the ACAP perspective rather than as an empirical test of absorptive capacity. Overall, the refined measurement framework provides a basis for future SEM research examining the relationships among CEP, TQM, GSCM, FP, and related organizational capabilities.

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