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Integrating sustainability and resilience in agri-food supply chains: A knowledge-based view of Thailand's pineapple industry in the digital era

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A R T I C L E I N F O

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A B S T R A C T

The COVID-19 pandemic, climate change, and market volatility have fundamentally challenged agricultural supply chains in developing economies. This study examines how knowledge-based integration capabilities affect resilience and sustainability in Thailand's pineapple industry, with digital capabilities as a moderating factor. We surveyed 186 organizations across the pineapple supply chain using stratified random sampling and analyzed data through partial least squares structural equation modeling. Our findings reveal that knowledge absorption, transformation, and utilization significantly enhance operational resilience, environmental sustainability, and social sustainability, with effects amplified by digital capabilities. The study extends knowledge-based view theory to agricultural contexts by identifying integration mechanisms specific to perishable products, demonstrates the complementary relationship between knowledge processes and digital capabilities, and provides a framework for developing integrated knowledge-digital strategies. Future research could explore these relationships across different agricultural products and regions.

1. Introduction

The convergence of multiple global disruptions from the COVID-19 pandemic to climate change and geopolitical tensions has fundamentally challenged conventional supply chain management paradigms [1]. Agricultural supply chains, particularly in developing economies, face unique vulnerabilities at this critical juncture [2]. While previous research has established connections between supply chain integration, agility, and performance [3,4], there remains a critical gap in understanding how these relationships function when confronted with systemic shocks in agricultural contexts [5].

The agricultural sector in Southeast Asia presents a compelling context for examining these questions. Thailand's pineapple industry the country's third-largest fruit export and a global leader providing 20% of world production exemplifies the complex challenges facing agricultural supply chains [6]. Despite its economic significance, this industry confronts multifaceted pressures from climate variability, labor constraints, digital transformation demands, and post-pandemic market reconfigurations [7]. Despite extensive research demonstrating positive relationships between supply chain integration and performance in manufacturing contexts including studies on internal integration [4,8], supplier integration [9,10], customer integration [11,12], and their combined effects [3,13–16], three critical knowledge gaps persist that are particularly acute in agricultural supply chains. First, existing frameworks developed for manufacturing contexts inadequately address the unique characteristics of agricultural supply chains perishability, seasonality, climate dependency, and the integration of traditional ecological knowledge with scientific approaches. Second, current research predominantly focuses on economic performance metrics, overlooking the multidimensional nature of agricultural sustainability that encompasses operational resilience, environmental regeneration, and social equity. Third, while digital transformation research has proliferated across industries, the specific role of digital capabilities in amplifying knowledge integration processes within agricultural contexts remains theoretically underdeveloped, with most studies treating digital technologies primarily as efficiency tools rather than knowledge amplifiers.

While existing literature has explored supply chain integration and agility relationships in manufacturing contexts [17,14], three critical knowledge gaps persist. First, the applicability of these frameworks to agricultural supply chains characterized by perishability, seasonality, and climate sensitivity remains underexplored [18]. Second, traditional

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performance metrics often overlook long-term sustainability and resilience dimensions critical to agricultural viability [19]. Third, the role of localized knowledge in agricultural supply chains, particularly in developing economies transitioning toward digital systems, is inadequately theorized [20]. Thailand's pineapple industry is well suited to address these deficiencies as an empirical application. Being the world's second-largest pineapple producer, this industry starts with smallholder farmers maintaining traditional knowledge and ends with modern processing plants for global markets, thus representing a natural lab to explore the integration of knowledge between heterogeneous organizational capabilities and digital maturities. This paper addresses these gaps by combining insights from the knowledge-based view [21] with circular economy considerations [22] on how knowledge-intensive integration relates to traditional performance metrics and novel sustainability effects. More specifically, the following three research questions were examined:

1) How do knowledge-based integration capabilities affect the resilience and sustainability of agricultural supply chains during systemic disruptions?
2) What role does digital transformation play in moderating these relationships in developing agricultural economic contexts?
3) How can localized knowledge networks strengthen global agricultural supply chains against future disruptions?

Our research makes three significant contributions. First, we develop a novel theoretical framework that integrates knowledge-based view with sustainability principles, extending beyond traditional economic performance to include environmental regeneration and social equity dimensions. Second, we identify specific knowledge-intensive integration mechanisms that enhance agricultural supply chain resilience during compound disruptions. Third, we provide an empirically grounded roadmap for agricultural businesses transitioning toward digitally enabled sustainable supply chains, particularly relevant for developing economies.

2. Theoretical foundation

2.1. Knowledge-based view in agricultural supply chains

The knowledge-based view (KBV) positions knowledge as the most strategically significant resource for competitive advantage [21,23]. It extends beyond traditional resource-based view [24,25] by emphasizing that competitive advantage derives not merely from possessing valuable resources but from the ability to create, integrate, and apply knowledge effectively. Unlike dynamic capabilities theory [26] which focuses on organizational routines for adaptation, KBV specifically highlights knowledge as the primary strategic resource and examines the mechanisms by which knowledge creates value [27]. KBV distinguishes between tacit knowledge (personal, context-specific, difficult to formalize) and explicit knowledge (codified, transmittable in formal language), recognizing that these knowledge types require different integration mechanisms [28,29]. This distinction is particularly relevant in agricultural contexts, where tacit knowledge about soil conditions, weather patterns, and crop management often represents generations of accumulated wisdom that resists simple codification and transfer [30].

Agricultural supply chains embody distinct knowledge characteristics that differentiate them from manufacturing contexts. First, agricultural knowledge is deeply embedded in local ecological contexts, with practices that evolve through generations of trial-and-error adaptation to specific environments [31,32]. Second, agricultural knowledge spans multiple domains from traditional ecological knowledge to scientific innovations and market intelligence requiring sophisticated integration mechanisms [33]. Third, agricultural knowledge is temporally dynamic, with seasonal variations and climate change necessitating continuous knowledge adaptation [30].

When applied to supply chain contexts, KBV emphasizes knowledge as a coordination mechanism that enables effective integration across organizational boundaries [34,35]. Knowledge sharing within supply chains faces significant barriers, including power asymmetries, competitive tensions, and technological incompatibilities [36,37]. These barriers are particularly pronounced in agricultural supply chains of developing economies, where smallholder farmers with tacit, location-specific knowledge interact with global processors possessing scientific and market expertise [38,39].

While KBV has been explored in manufacturing supply chains, its application to agricultural contexts remains limited, particularly regarding the integration of traditional knowledge with scientific approaches in developing economies facing digitalization pressures [40,41]. This gap is critical as agriculture increasingly navigates complex sustainability challenges requiring the integration of diverse knowledge types across organizational boundaries.

2.2. Supply chain integration through a knowledge lens

Supply chain integration traditionally encompasses the coordination of material, information, and financial flows across organizations [4,15]. However, this conceptualization often overlooks knowledge flows, particularly in agricultural contexts where knowledge integration involves complex socio-ecological systems [13]. By reconceptualizing supply chain integration through a knowledge lens, we identify three critical dimensions that reflect the unique knowledge processes in agricultural supply chains.

Knowledge absorption integration refers to mechanisms for identifying, acquiring, and assimilating external knowledge into organizational boundaries. This concept builds on absorptive capacity theory [42,43], which emphasizes an organization's ability to recognize valuable external knowledge and incorporate it into internal processes. In agricultural supply chains, knowledge absorption involves boundary-spanning activities that enable organizations to acquire diverse knowledge types from external sources, including market trends, technological innovations, climate patterns, and stakeholder expectations [44,45]. For Thai pineapple producers, this includes absorbing knowledge about international quality standards, changing consumer preferences, and emerging climate risks.

Knowledge transformation integration encompasses processes for recombining diverse knowledge sources into novel configurations that enable innovation and adaptation. This dimension draws on knowledge recombination theory [23,28], which emphasizes that value creation often stems from novel combinations of existing knowledge rather than entirely new knowledge. In agricultural contexts, knowledge transformation involves integrating traditional farming practices with scientific approaches, market intelligence, and digital technologies to create innovative solutions [46,47]. This integration often requires knowledge brokers who can bridge diverse knowledge domains and facilitate cross-functional collaboration [48,49]. For Thai pineapple supply chains, this includes recombining traditional cultivation knowledge with modern processing techniques and international market requirements.

Knowledge utilization integration refers to the systematic application of integrated knowledge in operational decisions and strategic initiatives. This dimension is built on knowledge application theory [50,51], which emphasizes that knowledge creates value only when effectively utilized in organizational processes. In agricultural supply chains, knowledge utilization involves implementing integrated knowledge in planting decisions, harvest timing, processing methods, and market strategies [52,53]. This often requires evidence-based management approaches that translate knowledge into actionable practices across supply chain partners [54,55]. For Thai pineapple producers, this includes applying market intelligence to production planning and integrated pest management knowledge to cultivation practices.

While traditional supply chain integration literature focuses on operational coordination, our knowledge-based conceptualization emphasizes cognitive integration processes that enable sustainable value creation in complex agricultural systems. This approach addresses the unique challenges of agricultural supply chains, including the integration of tacit and explicit knowledge, the bridging of traditional and scientific approaches, and the application of integrated knowledge in contexts characterized by uncertainty and complexity [56,57].

The knowledge integration challenges in agricultural supply chains are exacerbated by power asymmetries between small-scale producers and large processors or retailers [58,59], knowledge fragmentation across diverse stakeholders with specialized expertise [56], and cultural and technological barriers that impede knowledge flows across organizational boundaries [60,61]. Addressing these challenges requires dedicated integration mechanisms that facilitate knowledge absorption, transformation, and utilization across the entire supply chain.

2.3. Sustainability dimensions in agricultural supply chains

Sustainable supply chain management extends beyond traditional economic performance to encompass environmental and social dimensions [62,63]. In agricultural contexts, this multidimensional conceptualization is particularly critical, as agricultural activities directly impact ecological systems and rural communities [64,65]. We identify three key sustainability dimensions relevant to agricultural supply chains facing systemic disruptions.

Operational resilience refers to a supply chain's ability to anticipate disruptions, adapt to changing conditions, and maintain essential functions during turbulence [66,67]. In agricultural supply chains, resilience encompasses the capacity to withstand climate variability, market fluctuations, and pandemic-related disruptions while maintaining product flow and quality [68,69]. Resilience depends on diverse capabilities, including redundancy in critical resources, flexibility in production systems, and adaptive capacity in response to emerging threats [70,71]. For Thai pineapple supply chains, resilience involves maintaining production continuity despite labor shortages, climate variations, and market disruptions**.**

Environmental sustainability encompasses practices that preserve ecological balance, minimize resource consumption, and regenerate natural systems [72,73]. In agricultural contexts, this includes soil health management, biodiversity conservation, water use efficiency, and waste reduction throughout the supply chain [74,65]. Environmental sustainability increasingly incorporates circular economy principles that transform linear production models into regenerative systems where outputs become inputs for other processes [75,76]. For Thai pineapple producers, this includes reducing chemical inputs, implementing water conservation techniques, and utilizing processing waste as inputs for other agricultural processes.

Social sustainability refers to practices that ensure equitable participation, fair value distribution, and community wellbeing throughout the supply chain [77,78]. In agricultural contexts, this includes smallholder inclusion in value chains, fair labor practices, gender equity, and preservation of rural livelihoods [79,80]. Social sustainability requires participatory governance systems that enable diverse stakeholders to influence decision-making processes and benefit from agricultural activities [81,82]. For Thai pineapple supply chains, this includes ensuring fair returns to smallholder farmers, safe working conditions in processing facilities, and equitable access to market opportunities.

These sustainability dimensions exhibit complex interrelationships, with both tensions and complementarities [83,84]. Trade-offs may arise when environmental practices increase production costs, potentially conflicting with short-term economic goals or smallholder inclusion objectives. Conversely, synergies emerge when sustainable practices enhance product quality and market access, creating shared value across economic, environmental, and social dimensions [85,86]. Measuring these multidimensional outcomes presents significant challenges, particularly in agricultural contexts where impacts span diverse temporal and spatial scales [87,88].

Although some theorists recommend considering supply chain viability as a unified notion that combines resilience to and sustainability of supply chain [69], we follow a multiform approach and consider operational resilience, ecological and social sustainability as multi-dimensional constructs: separate but interrelated. This conceptual decision is theoretically motivated in the case of agricultural systems where these dimensions may show different temporal development, include different stakeholders, and lead to different forms of knowledge integration [89]. For example, operational resilience might necessitate rapid application of knowledge during a disruption, while environmental sustainability might rely more on longer-term knowledge transformation processes that bridge traditional and science-based knowledge. By isolating these dimensions, we can gain a more nuanced understanding of which integrative knowledge mechanisms and channels contribute to each facet of the performance of the agricultural supply chain, in a manner that is valuable for both understanding and practice. Potential areas for future research include extending our current findings by investigating how these dimensions interact in a dynamic way to form long-term supply chain health.

2.4. Digital capabilities in agricultural knowledge systems

Digital transformation is revolutionizing agricultural supply chains, from precision farming applications to blockchain-enabled traceability systems [90,91]. Digital capabilities defined as organizational competencies in leveraging digital technologies for value creation encompass technological infrastructure, digital skills, data governance mechanisms, and cultural readiness for technology adoption [92,93]. In agricultural contexts, these capabilities enable new approaches to knowledge management, from remote sensing of field conditions to artificial intelligence applications in supply chain optimization [94,41].

Digital technologies fundamentally transform knowledge processes in agricultural supply chains. First, they enhance knowledge absorption capabilities through IoT sensors that collect real-time data on soil conditions, crop health, and processing parameters [94,41]. Second, they facilitate knowledge transformation through big data analytics that identify patterns across diverse data sources, enabling novel knowledge combinations [95,96]. Third, they support knowledge utilization through decision support systems that translate integrated knowledge into actionable recommendations for farmers, processors, and distributors [97,98].

Despite these potential benefits, digital transformation in agricultural supply chains faces significant challenges, particularly in developing economies. The digital divide between large agribusinesses and smallholder farmers creates new knowledge asymmetries that can exacerbate power imbalances within supply chains [99,100]. Limited digital infrastructure in rural areas, inadequate technical skills among agricultural workers, and cultural resistance to technology adoption can impede the realization of digital benefits [101,98]. These challenges underscore the need for inclusive digitalization approaches that bridge technological gaps and ensure equitable participation in digital agriculture.

The complementary relationship between knowledge processes and digital capabilities creates significant opportunities for agricultural supply chains. Digital technologies can amplify knowledge integration by facilitating information sharing across organizational boundaries, enabling real-time collaboration among supply chain partners, and democratizing access to agricultural expertise [102,103]. Conversely, effective knowledge integration enhances the value of digital investments by ensuring that technological applications address context-specific challenges and incorporate diverse knowledge types, including traditional farming practices [104,105].

This complementarity indicates that digital capabilities could influence the connection between knowledge integration and sustainability results within agricultural supply chains. Organizations equipped with robust digital capabilities might enhance the advantages of knowledge integration, effectively converting absorbed, transformed, and applied knowledge into improved resilience and sustainability, in contrast to those with limited digital resources [93,106]. Digital capabilities promote knowledge integration through three interrelated mechanisms that produce synergistic effects in agricultural supply chains. These technologies expedite knowledge absorption by allowing for real-time data collection and information sharing across different boundaries; improve knowledge transformation by enabling the identification of patterns across varied data sources through advanced analytics; and enhance knowledge utilization by providing decision support systems that convert synthesized knowledge into practical recommendations [95,98,96]. This complementary perspective suggests that digital capabilities serve as multipliers of knowledge rather than standalone solutions, influencing the efficiency with which knowledge integration translates into tangible sustainable outcomes and enabling organizations with greater digital capabilities to extract more value from their investments in knowledge integration [93,106].

2.5. Systems theory perspective on knowledge-digital integration

Basing on system theory [107], we posit knowledge integration, digital capabilities, and sustainability outcomes as part of an interconnected adaptive system instead of as linear cause-effect relationships. This view acknowledges dynamic feedback loops in which learning from improved sustainability outcomes leads to knowledge of effective practices that is re-incorporated into the knowledge bases of organizations, resulting in continuous improvement cycles. The reciprocal relationship between knowledge processes and digital technologies generates new, integrated capabilities that are greater than the sum of their parts; digital capabilities may function as boundary objects for translating knowledge across different actors (e.g., traditional farmer and scientific researcher). This systems lens helps us understand why digital capabilities moderate knowledge-sustainability relationships by increasing the system's ability for knowledge processing, pattern recognition, and adaptive response rather than just reducing operational efficiencies.

3. Hypothesis development

Based on the theoretical foundations discussed above, we develop a conceptual framework that examines how knowledge-based integration affects sustainability outcomes in agricultural supply chains, with digital capabilities as a moderating factor (Fig. 1). This framework reflects the unique knowledge characteristics of agricultural supply chains and the multidimensional nature of sustainability in agricultural contexts.

3.1. Knowledge absorption integration and sustainability outcomes

Knowledge absorption integration enables organizations to identify, acquire, and assimilate external knowledge about market trends, technological innovations, environmental changes, and stakeholder expectations [42,43]. This capability is particularly critical in turbulent environments where rapid adaptation to changing conditions is essential for survival and sustainability [108,109].

In the context of operational resilience, knowledge absorption integration enhances an organization's capacity to anticipate potential disruptions, identify early warning signals, and prepare appropriate response strategies [110,71]. By absorbing knowledge about emerging climate patterns, market shifts, and supply chain vulnerabilities, agricultural organizations can develop preventive measures that minimize disruption impacts and accelerate recovery processes [111,112]. For example, Thai pineapple producers who actively absorb knowledge about seasonal weather forecasts can adjust planting schedules to avoid periods of extreme drought or flooding, enhancing their operational resilience during climate disruptions [89,69].

H1a. *Knowledge absorption integration positively influences operational resilience in agricultural supply chains.*

Regarding environmental sustainability, knowledge absorption integration enables organizations to identify innovative ecological practices, learn from environmental leaders, and incorporate sustainability standards into their operations [113,114]. By absorbing knowledge about regenerative farming techniques, circular economy approaches, and ecosystem services, agricultural organizations can implement practices that minimize environmental impact while maintaining productivity [115,30]. For instance, Thai pineapple producers who absorb knowledge about biological pest control methods can reduce chemical inputs while maintaining crop yields, enhancing environmental sustainability through reduced pollution and biodiversity preservation [74,116].

H1b. *Knowledge absorption integration positively influences environmental sustainability in agricultural supply chains.*

For social sustainability, knowledge absorption integration enables

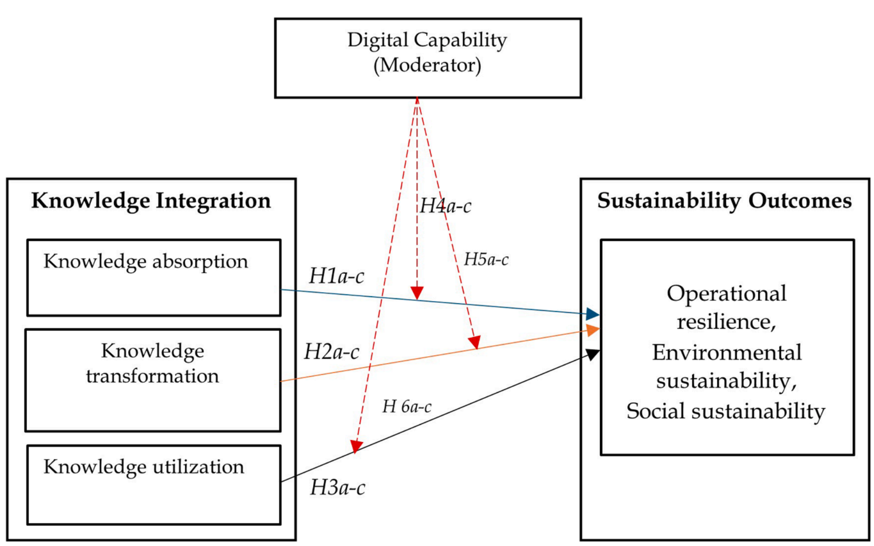

Fig. 1. Conceptual framework for knowledge integration and sustainability outcomes in agricultural supply chains. Solid arrows represent direct hypothesized relationships (H1-H3), while dashed arrows represent digital capability moderation effects (H4-H6).

organizations to understand stakeholder expectations, learn from inclusive business models, and incorporate community perspectives into decision-making processes [117,118]. By absorbing knowledge about fair trade practices, worker welfare standards, and inclusive value chain models, agricultural organizations can implement approaches that ensure equitable participation and benefit distribution [79,80]. For example, Thai pineapple processors who absorb knowledge about social certification requirements can implement practices that improve worker conditions and smallholder inclusion, enhancing social sustainability throughout the supply chain [119,120].

H1c. *Knowledge absorption integration positively influences social sustainability in agricultural supply chains.*

3.2. Knowledge transformation integration and sustainability outcomes

Knowledge transformation integration involves recombining diverse knowledge sources into novel configurations that enable innovation and adaptation [23,28]. This capability facilitates the integration of traditional ecological knowledge with scientific approaches and market intelligence, creating unique knowledge combinations that address complex sustainability challenges [121,122].

In terms of operational resilience, knowledge transformation integration enables organizations to develop innovative solutions to disruptions by recombining knowledge from diverse domains [123,124]. By integrating traditional farming wisdom with scientific approaches and digital technologies, agricultural organizations can create resilient practices that leverage both historical experience and contemporary innovation [125,126]. For instance, Thai pineapple supply chains that transform knowledge from weather forecasting, traditional planting calendars, and market demand patterns can develop flexible production systems that maintain continuity despite disruptions [127,70].

H2a. *Knowledge transformation integration positively influences operational resilience in agricultural supply chains.*

For environmental sustainability, knowledge transformation integration enables organizations to develop innovative ecological practices by combining traditional wisdom with scientific approaches [128,129]. By integrating indigenous knowledge about crop rotation, scientific understanding of nutrient cycles, and market requirements for sustainable products, agricultural organizations can create practices that enhance environmental outcomes while maintaining commercial viability [130,131]. For example, Thai pineapple producers who transform knowledge about traditional intercropping methods, scientific soil management, and organic certification requirements can implement agroecological systems that enhance biodiversity while meeting market demands [75,76].

H2b. *Knowledge transformation integration positively influences environmental sustainability in agricultural supply chains.*

Regarding social sustainability, knowledge transformation integration enables organizations to develop inclusive business models by combining community perspectives with market requirements [132,133]. By integrating smallholder knowledge with processor efficiency requirements and consumer preferences, agricultural organizations can create value chain configurations that ensure equitable participation while maintaining commercial competitiveness [134,85]. For instance, Thai pineapple supply chains that transform knowledge about smallholder cooperative models, efficient processing techniques, and premium market segments can develop inclusive systems that enhance rural livelihoods while meeting global market standards [81,82].

H2c. *Knowledge transformation integration positively influences social sustainability in agricultural supply chains.*

3.3. Knowledge utilization integration and sustainability outcomes

Knowledge utilization integration involves systematically applying integrated knowledge in operational decisions and strategic initiatives [50,51]. This capability ensures that absorbed and transformed knowledge translates into tangible practices that enhance sustainability throughout the supply chain [52,53].

For operational resilience, knowledge utilization integration enables organizations to implement effective disruption response strategies based on integrated knowledge about potential threats and mitigation approaches [135,136]. By applying early warning information, contingency plans, and recovery protocols in real-time decision-making, agricultural organizations can maintain functionality during disruptions and accelerate recovery processes [137,138]. For example, Thai pineapple processors who systematically apply knowledge about supply variability, production flexibility, and alternative sourcing options can maintain operational continuity despite disruptions in specific supply regions [68,67].

H3a. *Knowledge utilization integration positively influences operational resilience in agricultural supply chains.*

Regarding environmental sustainability, knowledge utilization integration enables organizations to implement ecological practices systematically throughout their operations [72,73]. By applying integrated knowledge about environmental impacts, resource efficiency techniques, and circular approaches in daily decisions, agricultural organizations can minimize ecological footprints while maintaining productivity [139,140]. For instance, Thai pineapple supply chains that systematically apply knowledge about water conservation techniques, waste-to-resource conversions, and energy efficiency measures can reduce environmental impacts throughout the production process [141,142].

H3b. *Knowledge utilization integration positively influences environmental sustainability in agricultural supply chains.*

For social sustainability, knowledge utilization integration enables organizations to implement inclusive practices systematically throughout their operations [143,144]. By applying integrated knowledge about fair trade principles, worker welfare standards, and community engagement approaches in procurement decisions and human resource practices, agricultural organizations can ensure equitable participation and benefit distribution [145,30]. For example, Thai pineapple processors who systematically apply knowledge about smallholder financing models, fair pricing mechanisms, and worker safety protocols can create socially sustainable value chains that benefit diverse stakeholders [146,147].

H3c. *Knowledge utilization integration positively influences social sustainability in agricultural supply chains.*

3.4. Moderating effects of digital capabilities

Digital capabilities technological infrastructure, skills, data governance mechanisms, and cultural readiness for technology adoption can potentially amplify the benefits of knowledge integration in agricultural supply chains [93,106]. These capabilities enable more efficient knowledge processes, facilitate collaboration across organizational boundaries, and enhance the application of integrated knowledge in decision-making [50,148].

For knowledge absorption integration, digital capabilities enhance the ability to identify and acquire external knowledge through advanced scanning technologies, digital collaboration platforms, and automated data collection systems [149,150]. Organizations with strong digital capabilities can access broader knowledge sources, process information more efficiently, and incorporate external insights more effectively into internal operations [94,41]. For example, Thai pineapple producers with IoT sensors can absorb real-time data about soil conditions, enabling more responsive adaptation to environmental changes than those relying solely on manual observations [102,103].

H4a-c. *Digital capabilities strengthen the positive relationships between knowledge absorption integration and sustainability outcomes (operational resilience, environmental sustainability, social sustainability) in agricultural supply chains.*

Regarding knowledge transformation integration, digital capabilities enhance the ability to recombine diverse knowledge sources through big data analytics, artificial intelligence applications, and digital collaboration tools [95,96]. Organizations with strong digital capabilities can identify patterns across disparate data sources, facilitate cross-functional collaboration, and accelerate innovation processes more effectively than those with limited digital maturity [151,152]. For instance, Thai pineapple processors with advanced analytics capabilities can identify optimal combinations of processing parameters, quality characteristics, and resource utilization that might remain undiscovered through manual analysis [153,154].

H5a-c. *Digital capabilities strengthen the positive relationships between knowledge transformation integration and sustainability outcomes (operational resilience, environmental sustainability, social sustainability) in agricultural supply chains.*

For knowledge utilization integration, digital capabilities enhance the ability to apply integrated knowledge in decision-making through decision support systems, blockchain traceability platforms, and mobile applications that deliver recommendations to diverse stakeholders [97,98]. Organizations with strong digital capabilities can implement knowledge-based practices more consistently, monitor outcomes more effectively, and adjust approaches more responsively than those with limited technological support [155,156]. For example, Thai pineapple supply chains with mobile advisory applications can deliver integrated knowledge about optimal harvesting practices directly to smallholder farmers, enabling more consistent implementation than those relying solely on traditional extension services [157,104].

H6a-c. *Digital capabilities strengthen the positive relationships between knowledge utilization integration and sustainability outcomes (operational resilience, environmental sustainability, social sustainability) in agricultural supply chains.*

4. Research methodology

This study employed a quantitative research approach to examine the relationships between knowledge-based integration dimensions, digital capabilities, and sustainability outcomes in Thailand's pineapple industry supply chain.

4.1. Population and sample

The target population comprised small and medium enterprises (SMEs) operating within Thailand's pineapple industry supply chain. According to the Department of Business Development database (2023), there are 466 registered SMEs in Thailand's pineapple industry across four main business categories: pineapple cultivation (14 companies), fruit and vegetable processing and packaging (110 companies), fruit and vegetable juice production (322 companies), and wine production excluding distilled spirits (20 companies).

Given the focus of our study on supply chain integration and sustainability, we included all registered SMEs across the entire pineapple supply chain. Following Hair et al.'s [158] recommendation of maintaining a minimum ratio of 5:1 between observations and estimated parameters, we determined that a minimum sample size of 185 was required based on our research model containing 37 parameters. To enhance methodological rigor, we conducted a formal a priori power analysis using *G*Power. Based on our conceptual model, we specified: effect size (f^2) = 0.15, statistical power = 0.80, alpha level = 0.05, and number of predictors = 11. The power analysis indicated a minimum required sample size of 123 observations. Our achieved sample of 186 observations provides statistical power of 0.92, exceeding the conventional threshold. We employed a stratified random sampling approach to ensure representation across the supply chain. The stratification proportions were determined to ensure representation across the pineapple supply chain ecosystem. Within each stratum defined by supply chain position, business size, and business type, organizations were randomly selected using systematic random sampling with a random starting point to ensure representative coverage while maintaining statistical rigor. The sample was stratified based on:

- Supply chain position (upstream: cultivators and input suppliers; midstream: processors and manufacturers; downstream: distributors and exporters)
- Business size (small: <50 employees; medium: 50–200 employees)
- Business type according to Thailand Standard Industrial Classification (TSIC) codes (01221: pineapple cultivation; 10,302: fruit and vegetable processing and packaging; 10,303: fruit and vegetable juice production; 11,022: wine production excluding distilled spirits)

A total of 200 questionnaires were distributed to the selected organizations, and 186 valid responses were received, yielding a response rate of 93%. The final sample included pineapple growers (34%), processors and manufacturers (28%), distributors and exporters (21%), input suppliers (10%), and industry associations (7%).

4.2. Measurement development

We developed measurement instruments through a three-stage process. First, we adapted established scales from existing literature. Second, we refined these scales through consultations with five subject matter experts (three academic researchers and two industry practitioners). Third, we conducted a pilot test with 30 organizations from the target population to assess the reliability and validity of the measurement items. All constructs were measured using multiple items on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Table 1 presents the operationalization of the key constructs.

Table 1
Operationalization of key constructs.

Construct	Dimensions	Adapted From
Knowledge Absorption Integration	Market knowledge, technical knowledge, Environmental knowledge	Makhloufi et al. [159]; Cuéllar et al. [160]; Xiong et al. [161]
Knowledge Transformation Integration	Cross-functional, Supply chain partner, Innovation-oriented	El Mokadem et al. [162]; Migdadi et al. [163]; Mrabet [164]
Knowledge Utilization Integration	Operational, Strategic, Collaborative	Migdadi [163]; Pal et al. [20]; Michel-Villarreal et al. [165]
Digital Capabilities	Infrastructure, Skills, Data governance, Digital culture	Michel-Villarreal et al. [165]; Belhadi et al. [19]; Khan et al. [166]
Operational Resilience	Response capacity, Continuity, Recovery	Ivanov & Dolgui [1]; Al Tera et al. [17]; Pereira et al. [167]
Environmental Sustainability	Resource efficiency, Circular practices, Ecosystem impact	Kabato et al. [168]; Sharma et al. [2]; Asgari [18]
Social Sustainability	Smallholder inclusion, Value distribution, Community wellbeing	Pereira et al. [167]; Mrabet [164]; Rattanawong et al. [7]

4.3. Data collection procedure

Data was collected through a structured questionnaire over a six-month period from November 2024 to April 2025. The questionnaire was administered in Thai and consisted of three sections: (1) organizational characteristics, (2) measurement items for the main constructs, and (3) an open-ended question for additional comments.

To maximize response rate and data quality, we used multiple data collection approaches depending on respondent preferences and accessibility:

- In-person administration during industry meetings and events (42% of responses)
- Email distribution with follow-up phone calls (35% of responses)
- Online survey platform for digitally advanced organizations (23% of responses)

Key informants were identified as owners, senior managers, or department heads with comprehensive knowledge of their organization's supply chain operations, knowledge management practices, and sustainability initiatives. Each participating organization provided one response. To address potential non-response bias, we compared early and late respondents [169] and found no significant differences in key characteristics ($p > 0.05$), suggesting non-response bias was not a concern. Common method bias was addressed through both procedural (ensuring respondent anonymity, separating predictor and criterion variables) and statistical remedies (Harman's single-factor test showed the first factor explained only 28.4% of variance).

4.4. Data analysis

We employed Partial Least Squares Structural Equation Modeling (PLS-SEM) using Smart PLS 4.0 to analyze the data due to our complex research model with multiple constructs and moderation effects [158]. PLS-SEM is particularly suitable for extending theoretical frameworks to new contexts and offers advantages in handling specialized industry studies with modest sample sizes [170]. Data screening procedures addressed missing values (<2%) using mean replacement and identified outliers through Mahala Nobis distance. We assessed common method bias using full collinearity approach, with VIF values below 3.3 indicating absence of severe bias [171].

For the measurement model, we evaluated: (1) internal consistency through Cronbach's alpha and composite reliability (CR > 0.70); (2) indicator reliability via outer loadings (>0.70); (3) convergent validity through Average Variance Extracted (AVE > 0.50); and (4) discriminant validity using Fornell-Larcker criterion and Heterotrait-Monotrait ratio (HTMT < 0.85) [172].

The structural model assessment included: (1) collinearity evaluation through VIF (<5.0); (2) path coefficients significance using bootstrapping with 5000 resamples; (3) coefficient of determination (R^2); (4) effect size (f^2); and (5) predictive relevance (Q^2) using blindfolding procedure [173].

For testing moderating effects of digital capabilities (H4-H6), we employed the two-stage approach in PLS-SEM and performed simple slope analysis at high (+1 SD) and low (−1 SD) levels of the moderator [174]. We controlled organizational characteristics (size, age, supply chain position, certification status) by including them as control variables in the model [175]. Control variables were operationalized as: organization size (natural log of employees), organization age (years since establishment), supply chain position (categorical: upstream = 1, midstream = 2, downstream = 3), and certification status (binary: 1 = certified, 0 = not certified). Significance testing of simple slopes was conducted using bias-corrected bootstrap confidence intervals (5000 resamples).

5. Results

5.1. Measurement model assessment

Table 2 presents the results of the measurement model assessment. All reflective constructs demonstrated satisfactory reliability with Cronbach's alpha values ranging from 0.783 to 0.926 and composite reliability (CR) values from 0.861 to 0.947, exceeding the recommended threshold of 0.70. Convergent validity was confirmed with average variance extracted (AVE) values ranging from 0.608 to 0.749, all above the 0.50 threshold. All indicator loadings were statistically significant ($p < 0.001$) and above 0.70, except for four items that had loadings between 0.653 and 0.695, which were retained as they did not adversely affect reliability and validity measures [158]. These items belonged to Knowledge Absorption Integration (2 items) and Social Sustainability (2 items) constructs and were retained due to their theoretical importance for construct content validity. The lowest AVE for Social Sustainability (0.608) reflects the complexity of measuring social dimensions in agricultural supply chains across diverse stakeholder groups.

Discriminant validity was supported through both the Fornell-Larcker criterion, with the square root of AVE for each construct exceeding its correlations with other constructs (Table 3), and the heterotrait-monotrait (HTMT) ratio analysis (Table 4), with all values below the conservative threshold of 0.85. Additionally, the assessment of common method bias using full collinearity tests yielded VIF values ranging from 1.76 to 2.84, all below the threshold of 3.3, indicating that common method bias was not a significant concern in this study.

5.2. Structural model assessment

After confirming the measurement model's validity and reliability, we examined the structural model. Table 5 presents the results of the hypothesis testing for direct effects. The R^2 values for the dependent variables were substantial: operational resilience (0.619), environmental sustainability (0.583), and social sustainability (0.547), indicating good explanatory power of the model. The adjusted R^2 values, which account for model complexity, were slightly lower but still substantial (0.608, 0.571, and 0.536, respectively). The Stone-Geisser Q^2 values, computed through blindfolding procedure (omission distance = 7), were all above zero (ranging from 0.312 to 0.425), supporting the model's predictive relevance.

To ensure robust estimation of path coefficients, we employed a bootstrapping procedure with 5000 resamples. Table 5 presents the detailed results of the hypothesis testing for direct effects, including the 95 % bias-corrected confidence intervals (BCCI). All path coefficients were statistically significant as none of the confidence intervals included zero, providing further support for our hypothesized relationships.

All hypothesized direct relationships (H1a-c, H2a-c, H3a-c) were supported with statistically significant path coefficients ($p < 0.05$). Knowledge utilization integration demonstrated the strongest effect on operational resilience ($\beta = 0.394$, $p < 0.001$, $f^2 = 0.282$), while knowledge transformation integration had the strongest impact on environmental sustainability ($\beta = 0.352$, $p < 0.001$, $f^2 = 0.236$). For

Table 2
Measurement model results.

Construct	Cronbach's α	CR	AVE	MSV
Knowledge Absorption Integration	0.891	0.918	0.651	0.48
Knowledge Transformation Integration	0.902	0.925	0.672	0.53
Knowledge Utilization Integration	0.874	0.908	0.667	0.51
Digital Capabilities	0.926	0.947	0.749	0.49
Operational Resilience	0.859	0.904	0.702	0.45
Environmental Sustainability	0.841	0.893	0.676	0.42
Social Sustainability	0.783	0.861	0.608	0.39

Note: CR = Composite Reliability; AVE = Average Variance Extracted, MSV = Maximum Shared Variance.

Table 3
Discriminant validity - Fornell-Larcker criterion.

Construct	1	2	3	4	5	6	7
1. Knowledge Absorption Integration	0.849						
2. Knowledge Transformation Integration	0.637	0.872					
3. Knowledge Utilization Integration	0.684	0.692	0.837				
4. Digital Capabilities	0.601	0.613	0.638	0.860			
5. Operational Resilience	0.609	0.621	0.663	0.601	0.889		
6. Environmental Sustainability	0.584	0.661	0.591	0.552	0.568	0.825	
7. Social Sustainability	0.546	0.593	0.613	0.582	0.503	0.618	0.819

Note: Bold diagonal elements are the square roots of AVE.

Table 4
Discriminant validity - HTMT ratio results.

Construct	1	2	3	4	5	6	7
1. Knowledge Absorption Integration	–						
2. Knowledge Transformation Integration	0.729	–					
3. Knowledge Utilization Integration	0.775	0.786	–				
4. Digital Capabilities	0.684	0.694	0.718	–			
5. Operational Resilience	0.692	0.703	0.746	0.684	–		
6. Environmental Sustainability	0.663	0.749	0.667	0.624	0.643	–	
7. Social Sustainability	0.620	0.673	0.691	0.659	0.569	0.765	–

social sustainability, knowledge transformation integration showed the strongest effect ($\beta = 0.315$, $p < 0.001$, $f^2 = 0.193$). The effect sizes (f^2) ranged from small to medium across all relationships.

The examination of 95 % bias-corrected confidence intervals provides additional insights into the precision of the estimated effects. The narrower confidence intervals for the relationship between knowledge utilization integration and operational resilience [0.251, 0.537] and between knowledge transformation integration and environmental sustainability [0.207, 0.497] indicate greater precision in these estimates, which aligns with their stronger effect sizes. Conversely, the relatively wider confidence intervals for the relationships involving social sustainability suggest some variability in these effects across the sample, although all relationships remain statistically significant as no interval contains zero.

The result of structural modification shown in Fig. 2.

5.3. Moderation analysis

To test the moderating effect of digital capabilities, we employed the two-stage approach in PLS-SEM. Table 6 presents the results of the moderation analysis.

Eight of the nine hypothesized moderation effects were supported. Digital capabilities significantly moderate the relationships between all three knowledge integration dimensions and operational resilience (H4a, H5a, H6a). Similarly, digital capabilities moderate the effects of knowledge absorption and transformation integration on both environmental and social sustainability (H4b, H4c, H5b, H5c). Digital capabilities also moderated the relationship between knowledge utilization integration and social sustainability (H6c). However, the moderation effect of digital capabilities on the relationship between knowledge utilization integration and environmental sustainability (H6b) was marginally significant ($\beta = 0.108$, $p = 0.059$) and thus not supported at the conventional $p < 0.05$ threshold. This finding differs from other significant moderation effects and warrants theoretical consideration, as it suggests potential boundary conditions for digital enhancement in agricultural knowledge processes.

The simple slope analysis revealed that the positive effects of knowledge integration dimensions on sustainability outcomes were consistently stronger at higher levels of digital capabilities (+1 SD) compared to lower levels (−1 SD). For example, the effect of knowledge absorption integration on operational resilience was significantly stronger ($\beta = 0.433$) at high levels of digital capabilities compared to low levels ($\beta = 0.139$).

Among the control variables, organization size had a significant positive effect on operational resilience ($\beta = 0.119$, $p = 0.027$) and environmental sustainability ($\beta = 0.126$, $p = 0.021$), while supply chain position and certification status significantly influenced social sustainability ($\beta = 0.132$, $p = 0.018$; $\beta = 0.145$, $p = 0.013$, respectively). Organization age did not have significant effects on any of the outcome variables.

The 95 % bias-corrected confidence intervals for the moderation effects further validate our findings. Notably, the confidence interval for $H_{6\beta}$ includes zero [−0.004, 0.220], confirming that the moderation effect of digital capabilities on the relationship between knowledge utilization integration and environmental sustainability is not statistically significant at the conventional $p < 0.05$ threshold. The marginally significant p-value (0.059) for this relationship is consistent with the confidence interval that barely crosses zero. For all other moderation effects, the confidence intervals exclude zero, supporting the statistical

Table 5
Structural model results - direct effects.

Hypothesis	Path	Path Coefficient (β)	*t*-value	p-value	f^2	95% BCCI	Result
H1a	KAI → OR	0.286	3.724	<0.001	0.153	[0.142, 0.429]	Supported
H1b	KAI → ENS	0.217	2.876	0.004	0.116	[0.073, 0.361]	Supported
H1c	KAI → SOS	0.194	2.354	0.019	0.089	[0.037, 0.351]	Supported
H2a	KTI → OR	0.248	3.195	0.001	0.142	[0.095, 0.401]	Supported
H2b	KTI → ENS	0.352	4.692	<0.001	0.236	[0.207, 0.497]	Supported
H2c	KTI → SOS	0.315	3.874	<0.001	0.193	[0.157, 0.473]	Supported
H3a	KUI → OR	0.394	5.352	<0.001	0.282	[0.251, 0.537]	Supported
H3b	KUI → ENS	0.192	2.471	0.014	0.104	[0.042, 0.342]	Supported
H3c	KUI → SOS	0.297	3.516	<0.001	0.175	[0.132, 0.462]	Supported

Note: KAI = Knowledge Absorption Integration; KTI = Knowledge Transformation Integration; KUI = Knowledge Utilization Integration; OR = Operational Resilience; ENS = Environmental Sustainability; SOS = Social Sustainability; BCCI = Bias-Corrected Confidence Intervals.

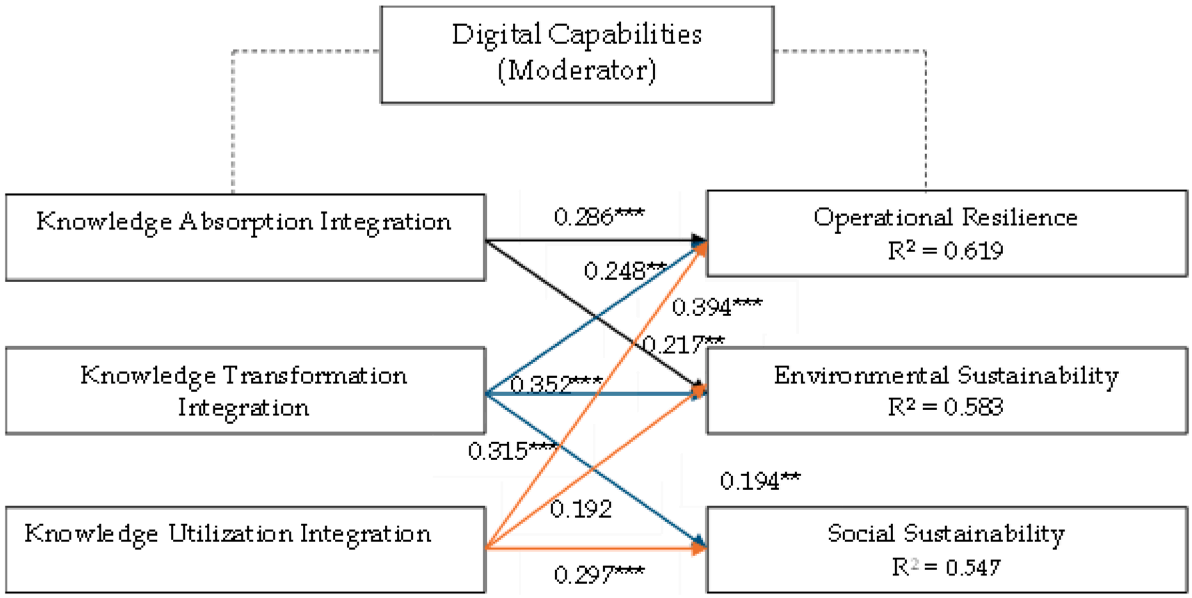

Fig. 2. The result of structural modification.

Table 6
Moderation effects of digital capabilities.

Hypothesis	Interaction Path	Path Coefficient (β)	*t*-value	p-value	95 % BCCI	Result
H4a	KAI × DC → OR	0.147	2.673	0.008	[0.042, 0.252]	Supported
H4b	KAI × DC → ENS	0.163	2.912	0.004	[0.056, 0.270]	Supported
H4c	KAI × DC → SOS	0.109	1.968	0.049	[0.003, 0.215]	Supported
H5a	KTI × DC → OR	0.138	2.426	0.016	[0.029, 0.247]	Supported
H5b	KTI × DC → ENS	0.191	3.358	<0.001	[0.082, 0.300]	Supported
H5c	KTI × DC → SOS	0.127	2.254	0.025	[0.018, 0.236]	Supported
H6a	KUI × DC → OR	0.174	3.106	0.002	[0.065, 0.283]	Supported
H6b	KUI × DC → ENS	0.108	1.891	0.059	[−0.004, 0.220]	Not supported
H6c	KUI × DC → SOS	0.152	2.735	0.006	[0.045, 0.259]	Supported

Note: DC = Digital Capabilities; × indicates interaction term; BCCI = Bias-Corrected Confidence Intervals.

significance of these relationships.

5.4. Control variables and additional analysis

To address the reviewer's concern about control variables and simple slope analysis mentioned in the methodology, we present the detailed results of these analyses that provide important context for our main findings.

5.4.1. Control variables effects

The control variables included in our model showed several significant relationships with sustainability outcomes, as summarized in Table 7. These effects provide additional insights into how organizational characteristics influence sustainability performance beyond the knowledge integration capabilities examined in our main hypotheses.

Table 7
Control variables effects on sustainability outcomes.

Control Variable	Operational Resilience	Environmental Sustainability	Social Sustainability
Organization Size	$\beta = 0.119$, $p = 0.027$*	$\beta = 0.126$, $p = 0.021$*	β = NS
Organization Age	β = NS	β = NS	β = NS
Supply Chain Position	β = NS	β = NS	$\beta = 0.132$, $p = 0.018$*
Certification Status	β = NS	β = NS	$\beta = 0.145$, $p = 0.013$*

* $p < 0.05$; NS = Not Significant.

Organization size demonstrated positive significant effects on both operational resilience and environmental sustainability, suggesting that larger organizations possess greater resources and capabilities to invest in resilience-building activities and environmental initiatives. Supply chain position significantly influenced social sustainability, with downstream organizations showing higher social sustainability scores, likely reflecting their greater exposure to international standards and consumer expectations. Certification status positively affected social sustainability, indicating that certified organizations implement more comprehensive social practices. Organization age showed no significant effects across any sustainability dimensions.

5.4.2. Simple slope analysis results

As mentioned in our methodology, we conducted simple slope analysis to examine how the effects of knowledge integration dimensions vary at different levels of digital capabilities. Table 8 presents the detailed results of this analysis, showing the conditional effects at low (−1 SD) and high (+1 SD) levels of digital capabilities.

The results of simple slope analysis indicate the consistent patterns of digital capability amplification in most of the knowledge integration interaction. The moderating role of digital capability in the relationship between knowledge integration and sustainability performance is positively and systematically significant.

For instance, the impact of knowledge absorption integration on operational resilience is amplified by a factor of three from $\beta = 0.139$ at low levels of digital capability up to $\beta = 0.433$ at high levels of digital capability. Also, the impact of knowledge transformation integration is

Table 8
Simple slope analysis for knowledge integration effects.

Relationship	Low DC (−1 SD)	Main Effect	High DC (+1 SD)
KAI → OR	$\beta = 0.139$*	$\beta = 0.286$***	$\beta = 0.433$***
KAI → ENS	$\beta = 0.054$	$\beta = 0.217$**	$\beta = 0.380$***
KAI → SOS	$\beta = 0.085$	$\beta = 0.194$*	$\beta = 0.303$**
KTI → OR	$\beta = 0.110$	$\beta = 0.248$***	$\beta = 0.386$***
KTI → ENS	$\beta = 0.161$*	$\beta = 0.352$***	$\beta = 0.543$***
KTI → SOS	$\beta = 0.188$*	$\beta = 0.315$***	$\beta = 0.442$***
KUI → OR	$\beta = 0.220$**	$\beta = 0.394$***	$\beta = 0.568$***
KUI → SOS	$\beta = 0.145$	$\beta = 0.297$***	$\beta = 0.449$***

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$
Note: DC = Digital Capabilities; KAI/KTI/KUI = Knowledge Absorption/Transformation/Utilization Integration; OR/ENS/SOS = Operational Resilience/Environmental/Social Sustainability.

higher on environmental sustainability from $\beta = 0.161$ to $\beta = 0.543$, depending on the level of digital capability. Specifically, knowledge utilization integration continues to contribute positively to operational resilience even when at low levels of digital capabilities ($\beta = 0.220$, $p < 0.01$), highlighting the value that this dimension offers irrespective of the extent to which an organization is digitized. Nevertheless, the amplification magnitude remains pronounced and the coefficient of association grows to $\beta = 0.568$ at high digital capability.

These trends support that digital capabilities are a critical enhancer of knowledge integration processes, and organizations with higher levels of digital maturity can generate more sustainability benefits from their knowledge integration initiatives.

6. Discussion

Our findings provide significant insights into how knowledge-based integration capabilities affect sustainability outcomes in agricultural supply chains, particularly in the context of Thailand's pineapple industry. The results demonstrate that all three knowledge integration dimensions absorption, transformation, and utilization significantly contribute to organizational resilience and sustainability, with these relationships strengthened by digital capabilities.

6.1. Knowledge integration and supply chain sustainability

The strong positive relationships between knowledge integration dimensions and sustainability outcomes extend our understanding of the knowledge-based view in several ways. Knowledge utilization integration demonstrated the strongest effect on operational resilience ($\beta = 0.394$, $p < 0.001$), suggesting that the application of integrated knowledge to decision-making processes is particularly crucial for maintaining functionality during disruptions. This finding aligns with Ivanov & Dolgui's [1] conceptualization of resilience as the ability to effectively deploy resources during turbulent periods, where integrated knowledge becomes a critical resource for adaptive response. This result extends beyond traditional supply chain resilience literature by highlighting that in agricultural contexts, the ability to apply knowledge systematically in response to disruptions is more critical than simply possessing diverse knowledge sources. As Ponomarov & Holcomb [67] noted, resilience emerges from the application of knowledge in timely and contextually appropriate ways, rather than mere knowledge possession.

This finding provides unique theoretical insight by demonstrating that in agricultural contexts, knowledge application capabilities matter more than knowledge acquisition or creation capabilities for operational resilience. This differs from manufacturing studies where knowledge absorption typically shows the strongest effects, highlighting the distinctive nature of agricultural knowledge systems where practical implementation under uncertainty becomes the critical success factor. Our findings suggest that Thai pineapple organizations that effectively utilize their integrated knowledge about climate patterns, market shifts, and production alternatives demonstrate greater operational continuity during disruptions than those with equivalent knowledge that remains unapplied.

For environmental sustainability, knowledge transformation integration showed the strongest impact ($\beta = 0.352$, $p < 0.001$), highlighting how the recombination of diverse knowledge sources enables innovative environmental practices. This result extends Kabato et al.'s [168] work on sustainable agriculture by demonstrating how knowledge transformation underpins the development of circular agricultural practices. The integration of traditional ecological knowledge with scientific innovations creates unique combinations that enhance resource efficiency and ecosystem preservation. This finding constitutes the novel contribution of theory. It shows that in agriculture, it is not so much that environmental innovation depends on the creation of new knowledge; as recombinations from the sideline knowledge of many different people. Unlike in manufacturing, where innovation is driven by R&D, environmental sustainability in agriculture can only be achieved by imaginatively integrating existing knowledge domains like traditional ecological wisdom, scientific research, and market needs into context-specific solutions. This extends the ideas of knowledge-based view theory to agricultural contexts by identifying recombination as the main innovation process.

This finding contributes to environmental sustainability literature by revealing that in agricultural contexts, innovation emerges primarily from novel recombinations of existing knowledge rather than entirely new knowledge creation. As Tittonell [129] and Rosset & Altieri [128] observed, agroecological innovations often result from integrating traditional farming wisdom with scientific approaches and market requirements. Our results suggest that Thai pineapple producers who effectively transform knowledge from different domains combining traditional intercropping techniques with modern resource efficiency approaches and certification requirements achieve greater environmental sustainability than those focusing solely on knowledge absorption or utilization.

Similarly, knowledge transformation integration demonstrated the strongest effect on social sustainability ($\beta = 0.315$, $p < 0.001$), followed closely by knowledge utilization ($\beta = 0.297$, $p < 0.001$). These findings complement Pereira et al.'s [167] research on supply chain sustainability learning by revealing the mechanisms through which knowledge integration enhances equitable participation and value distribution. The ability to transform diverse knowledge sources particularly combining smallholder expertise with market intelligence appears fundamental to creating socially sustainable supply systems.

This result enriches social sustainability literature by highlighting that inclusive agricultural supply chains require both knowledge transformation capabilities to create innovative inclusive business models and knowledge utilization capabilities to implement these models effectively. As Gradl & Jenkins [132] and Kelly et al. [133] noted, social sustainability emerges from business models that integrate diverse stakeholder perspectives while maintaining commercial viability. Our findings suggest that Thai pineapple supply chains that transform knowledge about smallholder cooperative structures, processor efficiency requirements, and premium market segments and then systematically apply this transformed knowledge achieve greater social sustainability than those focusing solely on knowledge absorption. These findings uniquely demonstrate that social sustainability requires both knowledge transformation capabilities to create inclusive business models and knowledge utilization capabilities to implement them effectively. This dual requirement distinguishes agricultural supply chains from other industries where social sustainability often focuses on compliance rather than innovation, highlighting how agricultural contexts demand more sophisticated knowledge integration for stakeholder engagement across diverse cultural and socioeconomic boundaries.

Collectively, these findings extend knowledge-based view theory beyond its traditional manufacturing applications by revealing how different knowledge integration dimensions serve specialized functions in agricultural sustainability contexts. The pattern of effects utilization for resilience, transformation for environmental sustainability, and both for social sustainability represents a unique theoretical contribution that reflects the multifaceted challenges of agricultural supply chain management in developing economies.

Our research contributes, theoretically, in three important ways to the extension of the KBV theory to the agribusiness context. First, we show that distinct knowledge integration dimensions play specific roles in agricultural sustainability: Utilization is more important for the maintenance of operations and transformation for environmental sustainability, compared with manufacturing where mostly knowledge absorption is at stake. Second, we develop a theory of digital boundary conditions and demonstrate that certain agricultural practices are based on analog processes that cannot be reduced to digital encoding, thereby uncovering a more nuanced understanding of knowledge processes and digital technologies. Third, we draw from system theory lenses to show that knowledge integration, digital capabilities, and sustainability outcomes act as an interdependent adaptive system and not linear cause-effect relationships, offering further insights into the dynamics of the agricultural supply chain.

6.2. *The moderating role of digital capabilities*

Our moderation analysis revealed that digital capabilities significantly strengthen the relationships between knowledge integration dimensions and sustainability outcomes in most cases. This finding extends the work of Michel-Villarreal et al. [165] by demonstrating how digital technologies serve as knowledge amplifiers rather than mere efficiency tools in agricultural contexts. This finding extends digital transformation theory by identifying analog domains within agricultural knowledge where digital capabilities provide limited enhancement. Unlike knowledge absorption (where digital sensors and data analytics clearly add value) or knowledge transformation (where computational power enables novel combinations), knowledge utilization for environmental sustainability often involves irreducibly analog processes such as tactile soil assessment, multisensory pest identification, and contextual adaptation to highly localized conditions that resist digital codification. The particularly strong moderation effect on the relationship between knowledge transformation integration and environmental sustainability ($\beta = 0.191$, $p < 0.001$) indicates that digital technologies are especially valuable for enabling innovative environmental practices.

This result contributes to digital agriculture literature by revealing that digital capabilities enhance sustainability outcomes primarily by amplifying knowledge integration processes rather than through direct effects. As Warner & Wäger [106] and Verhoef et al. [93] noted, digital technologies create value by enhancing existing organizational capabilities rather than as standalone interventions. Our findings suggest that Thai pineapple organizations with advanced digital capabilities can leverage their knowledge integration processes more effectively than those with limited digital maturity, creating synergistic benefits that exceed the sum of individual capabilities.

The simple slope analysis further clarifies these effects, showing that the positive impact of knowledge integration on sustainability outcomes is substantially stronger at higher levels of digital maturity. For example, the effect of knowledge absorption integration on operational resilience increases from $\beta = 0.139$ at low digital capability levels to $\beta = 0.433$ at high levels. This substantial difference indicates that agricultural organizations investing in both knowledge integration and digital capabilities can achieve synergistic benefits, supporting Belhadi et al.'s [19] findings on digital capabilities in agri-food supply chains. The significant variation in digital capabilities across organization types (as shown in Section 5.4) provides important context for understanding these moderation effects. Downstream organizations demonstrated significantly higher digital capabilities ($M = 3.92$) compared to midstream ($M = 3.47$) and upstream organizations ($M = 2.84$), while medium enterprises showed higher capabilities than small enterprises. This systematic variation suggests that the amplification benefits of digital capabilities are not equally accessible across the supply chain, potentially creating new forms of competitive advantage for technologically advanced organizations while highlighting the need for inclusive digitalization strategies.

This pattern extends to most hypothesized relationships, with digital capabilities consistently amplifying the benefits of knowledge integration for sustainability outcomes. However, the non-significant moderation effect between knowledge utilization integration and environmental sustainability ($\beta = 0.108$, $p = 0.059$) suggests that this relationship may be more complex than initially hypothesized. As Asgari [18] noted, some environmental practices in agriculture rely on tacit knowledge and analog approaches that may not necessarily benefit from digital augmentation in all contexts.

This exception highlights the nuanced relationship between knowledge processes and digital technologies in agricultural contexts. While digital capabilities generally enhance knowledge integration, certain environmental practices particularly those deeply embedded in traditional farming approaches may rely on tacit knowledge application that digital technologies cannot easily enhance. This finding contributes to digital agriculture literature by identifying boundary conditions for the complementary relationship between knowledge processes and digital capabilities.

6.3. *Implications for knowledge-based sustainability in agricultural supply chains*

The consistent positive effects across all knowledge integration dimensions highlight the multifaceted nature of knowledge as a strategic resource in agricultural contexts. While traditional manufacturing-focused supply chain research often emphasizes technical and market knowledge [17], our findings demonstrate that agricultural supply chains must integrate diverse knowledge types including traditional ecological knowledge, scientific innovations, and market intelligence to achieve sustainability.

This insight extends the knowledge-based view beyond its traditional application in manufacturing contexts to the unique challenges of agricultural supply chains. As Kogut & Zander [23] and Grant [21] observed, competitive advantage emerges from the integration of specialized knowledge across organizational boundaries. Our findings suggest that in agricultural contexts, this integration must span not only organizational boundaries but also diverse knowledge systems from traditional farming practices to scientific research and market intelligence to address the complex sustainability challenges facing agricultural supply chains.

The varying strengths of relationships between knowledge dimensions and sustainability outcomes suggest that organizations should prioritize certain knowledge integration practices based on their specific goals. For operational resilience, strengthening knowledge utilization capabilities should be prioritized; for environmental sustainability, enhancing knowledge transformation processes is most critical; and for social sustainability, both transformation and utilization capabilities deserve attention.

These findings expand on Pal et al.'s [20] combined dynamic capabilities and knowledge-based view by demonstrating how different knowledge processes contribute to specific aspects of resilience and sustainability. The integration of traditional farming knowledge with scientific approaches and market intelligence creates unique knowledge configurations that enhance adaptability to climate variability, market fluctuations, and social pressures simultaneously.

For practitioners, our results indicate implementation strategies that are guided by sustainability or organizational priorities. Organization focusing on operational resilience can also stand up a dynamic approach to early warning systems, which may combine Internet of Things (IoT) sensors for environmental sensing with market intelligence platforms and include teams with pre-crafted positions designed for supply chain coordination and alternative sourcing. Those centered on environmental sustainability will create innovation teams, which will meet monthly to organically meld traditional and scientific knowledge (e.g., melding indigenous intercropping practices with precision ag data) and partner with local universities to co-develop sustainable practices for the region. They include the development of socially sustainable organizations aimed at the development of procurement systems that would entail an inclusive type of scheme with the smallholder farmers having a guaranteed purchase agreement, the establishment of farmer training centers to conserve indigenous knowledge and also teach modern practices, as well as creating a clear pricing strategy that would involve regular community engagement sessions to explain the basis for pricing. To policymakers in the less developed world, sustaining agricultural growth takes focused institutional effort. It will also create essential infrastructure like the national agricultural knowledge database, which will pool traditional practices, scientific research, and market intelligence that can be accessed through mobile applications and regional Knowledge Integration Centers that house agricultural extension workers, digital literacy trainers, and market analysts together. Digital skills development can focus on subsidized programs for smartphone and internet use for rural agricultural communities, requirements for digital literacy in agricultural extension, and public-private partnerships for creating agricultural apps in local languages. Institutional support measures could include requirements for reporting supply chain transparency among agricultural exporters above a certain level of revenue to help counter information asymmetry, revolving loan funds for sustainable technology adoption with an emphasis on knowledge sharing, and agricultural innovation prizes that celebrate the successful incorporation of both traditional and modern knowledge.

Our results help us to understand knowledge integration capabilities, but our model emphasizes internal organizational capabilities. Policies such as those related to government support, institutional infrastructure, and regulations may consequently assume a great deal of importance in the transition to technology adoption and environmental sustainability in the case of Thailand or other developing countries. The lack of these exogenous facilitating elements in our model is a limitation that will clearly need to be taken into consideration in future work. Policies encouraging acquisition of digital literacy competencies, industry associations' activities, information sharing, and institutional development in technology transfer might moderate the relationships observed inside our exploration. Further exploration is needed to understand how these enablers interact with internal knowledge integration capabilities to develop a broader ecosystem view, which is needed for sustainable agricultural supply chains. Recent research has shown the positive reinforcement role of government support on the technology adoption-success linkage under developing economies [176].

Our slope tests show that the effect of knowledge integration approaches differs greatly between stages of digital maturity of an organization, which is of great significance for agricultural practitioners. Firms that are strong in digital capabilities should engage in knowledge transformation when maximizing their environmental sustainability impacts, but at the same time use digital technology to absorb knowledge for operational resiliency reasons. These digitally savvy companies can execute holistic approaches that leverage traditional farmers' knowledge along with cutting-edge data analytics, resulting in sustainability synergies. In contrast, for organizations with lower digital capability, the focus should be on reinforcing knowledge use, as it can be effective across different stages of digital maturity, is high returning in terms of operational resilience, and does not require large investments in technology. Our results could inform policy by emphasizing that digital capability benefits are not evenly distributed through supply chains, resulting in potential inequities between large agribusinesses and smallholder farmers, and therefore would require inclusive digitalization strategies that combine maintaining traditional knowledge with providing wider access to digital agricultural technologies.

6.4. *Limitations and future research directions*

6.4.1. *Cross-sectional design limitations*

Our cross-sectional research design severely limits the ability to draw causal inferences in a number of important respects. First, this design does not allow for the establishment of temporal sequencing, and it is difficult to know if capabilities to integrate knowledge cause better sustainability results, or if organizations with superior sustainability performance are better placed to invest in knowledge integration capabilities. This reverse causality issue is especially pertinent in relation to operational resilience as organizations already having resilient capabilities might have more resources and incentives to establish elaborate knowledge integration processes. Second, our static snapshot is unable to account for the dynamic co-evolution of knowledge capabilities and digital maturity that are likely to mutually coevolve, strengthening each other over time.

6.4.2. *Common method bias limitations*

Although we employed procedural and statistical controls, the fact that we used a single key informant from each organization raises issues of common method bias (CMB). This methodological decision could have impacted our findings in three ways. The first is that individual informants might provide reflection-influenced responses based on personal viewpoints, designated positions, and cognitive biases, especially when dealing with subjective constructs like social and environmental sustainability, which can have significantly different perspectives across functional areas inside the same organization. The second reason is that respondents might be susceptible to acquiescence bias or social desirability bias when they are rating their organization's performance on several related constructs. And third, the short time interval between predicting and outcome measures could have inflated associations through same-source bias. Although CMB did not appear to be a major issue based on our statistical tests, measurement error is a possibility.

6.4.3. *Future research directions*

Future research could avoid these limitations through longitudinal studies capable of both following the co-evolution of knowledge integration capabilities, digital maturity levels, and sustainability performance over time, especially investigating how these relationships change in the face of varieties of disruptions, such as climatic events, market shocks, or technological innovations. Multi-informant designs should also triangulate data by combining multiple data sources (from operations managers, sustainability managers, IT managers, etc.) and different parts of the organization to spread out different dyadic relationships in the organization. It would be advantageous to include more objective measures by adding certification records, environmental audit scores, and financial performance data when developing the construct and not relying on perception measures alone.

7. Conclusion

This study examined how knowledge-based integration capabilities affect sustainability outcomes in Thailand's pineapple industry supply chain, with digital capabilities serving as a moderating factor. Our findings provide several important theoretical and practical contributions to understanding sustainable agricultural supply chains in the digital era.

First, we demonstrated that all three dimensions of knowledge-based integration absorption, transformation, and utilization positively influence operational resilience, environmental sustainability, and social sustainability in agricultural supply chains. These relationships highlight the strategic importance of knowledge as a resource for enhancing sustainability across multiple dimensions. Particularly, knowledge utilization integration showed the strongest effect on operational resilience, knowledge transformation integration on environmental sustainability, and both transformation and utilization on social sustainability.

Second, our results confirmed that digital capabilities significantly moderate most relationships between knowledge integration dimensions and sustainability outcomes, with the effect of knowledge integration on sustainability being stronger at higher levels of digital maturity. This finding emphasizes the complementary nature of knowledge integration and digital capabilities in creating sustainable agricultural supply systems, particularly in developing economy contexts.

Third, our research extends the knowledge-based view beyond manufacturing contexts to agricultural supply chains, demonstrating how the integration of diverse knowledge types of traditional ecological knowledge, scientific innovations, and market intelligence creates unique capabilities that enhance resilience and sustainability in ways particularly relevant to agricultural systems.

For practitioners, our findings suggest that agricultural organizations should develop comprehensive knowledge integration strategies that address all three knowledge dimensions, while prioritizing specific dimensions based on their sustainability goals. These efforts should be complemented by appropriate digital capability investments to maximize impact. Policymakers in developing economies can support sustainable agricultural development by creating programs that strengthen both knowledge integration processes and digital capabilities simultaneously, particularly focusing on initiatives that preserve and integrate traditional agricultural knowledge with modern scientific approaches.

Future research should explore these relationships across different agricultural products and regional contexts, examine how specific digital technologies (e.g., blockchain, IoT, AI) interact with different knowledge integration dimensions, and investigate how knowledge integration capabilities develop over time in response to evolving sustainability challenges. Additionally, research on power dynamics in knowledge sharing between large agribusinesses and smallholder farmers could provide important insights into the equity dimensions of knowledge-based sustainability in global agricultural supply chains.

In conclusion, as agricultural systems worldwide face unprecedented challenges from climate change, market volatility, and resource constraints, the ability to effectively integrate and apply diverse knowledge becomes increasingly critical. Our study provides both theoretical foundations and practical approaches for developing knowledge-intensive agricultural supply chains capable of thriving amid uncertainty while advancing sustainability goals.

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Institutional review board statement

This research did not require formal ethical approval according to the institutional guidelines of Rajamangala University of Technology Lanna and Khon Kaen University, as it involved only anonymous organizational-level data collection through questionnaires with informed consent from participants and did not involve sensitive personal information or vulnerable populations.

Informed consent statement

Informed consent was obtained from all organizational representatives involved in the study. The consent form outlined the research objectives, procedures, voluntary participation, the right to withdraw at any time, data confidentiality measures, and use of aggregated results for academic publications. No personally identifiable information was collected, and all data was anonymized during analysis and reporting.

Data availability statement

The data presented in this study are not publicly available due to privacy and confidentiality agreements with the participating organizations in Thailand's pineapple industry. The dataset contains commercially sensitive information and demographic details that could potentially identify individual respondents or their organizations. Aggregated statistical results and anonymized data subsets may be made available upon reasonable request from the corresponding author, subject to approval from the participating organizations. However, an anonymized data subset containing only variable scores without demographic or firmographic identifiers may be made available upon reasonable request from qualified researchers for the sole purpose of methodological replication. Such requests should specify the intended use and demonstrate adherence to ethical research standards, with availability subject to approval from the corresponding author and participating organizations.

CRediT authorship contribution statement

Konpapha Jantapoon: Writing – review & editing, Writing – original draft, Project administration, Formal analysis, Conceptualization. **Phutthichai Amornwattahcharoenchai:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

References

[1] D. Ivanov, A. Dolgui, A digital supply chain twin for managing the disruption risks and resilience in the era of industry 4.0, Prod. Plan. Control 32 (9) (2021) 775–788.

[2] M. Sharma, S. Luthra, S. Joshi, A. Kumar, Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic, Int. J. Logist. Res. Appl. 25 (4–5) (2022) 433–453.

[3] R. Dubey, A. Gunasekaran, D.J. Bryde, Y.K. Dwivedi, T. Papadopoulos, Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting, Int. J. Prod. Res. 58 (11) (2020) 3381–3398.

[4] B.B. Flynn, B. Huo, X. Zhao, The impact of supply chain integration on performance: a contingency and configuration approach, J. Oper. Manag. 28 (1) (2010) 58–71.

[5] J.R. de Vries, J.A. Turner, S. Finlay-Smits, A. Ryan, L. Klerkx, Trust in agri-food value chains: a systematic review, Int. Food Agribus. Manag. Rev. 26 (2) (2023) 175–198.
[6] National Statistical Office, Ministry of Digital Economy and Society, Statistical Yearbook Thailand, Available online: https://www.nso.go.th/public/e-book/Statistical-Yearbook/SYB-2023, 2023. accessed on 17 May 2025.
[7] A. Rattanawong, P. Ongkunaruk, T.D. Leingpibul, Investigating the structural composition of contemporary sustainable organic agriculture supply chains: a case study from Thailand, AGRAR.: J. Agribus. Rural Dev. Res. 10 (1) (2024) 136–155.
[8] X. Zhao, B. Huo, W. Selen, J.H.Y. Yeung, The impact of internal integration and relationship commitment on external integration, J. Oper. Manag. 29 (1–2) (2011) 17–32.
[9] P. Lii, F.I. Kuo, Innovation-oriented supply chain integration for combined competitiveness and firm performance, Int. J. Prod. Econ. 174 (2016) 142–155.
[10] T. Schoenherr, M. Swink, Revisiting the arcs of integration: cross-validations and extensions, J. Oper. Manag. 30 (1–2) (2012) 99–115.
[11] S. Devaraj, L. Krajewski, J.C. Wei, Impact of eBusiness technologies on operational performance: the role of production information integration in the supply chain, J. Oper. Manag. 25 (6) (2007) 1199–1216.
[12] C. Droge, J. Jayaram, S.K. Vickery, The effects of internal versus external integration practices on time-based performance and overall firm performance, J. Oper. Manag. 22 (6) (2004) 557–573.
[13] C. Ataseven, A. Nair, Assessment of supply chain integration and performance relationships: a meta-analytic investigation of the literature, Int. J. Prod. Econ. 185 (2017) 252–265.
[14] M. Farrukh Shahzad, H. Liu, H. Zahid, Industry 4.0 technologies and sustainable performance: do green supply chain collaboration, circular economy practices, technological readiness and environmental dynamism matter? J. Manuf. Technol. Manag. 36 (1) (2025) 1–22.
[15] C.Y. Wong, S. Boon-Itt, C.W. Wong, The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance, J. Oper. Manag. 29 (6) (2011) 604–615.
[16] W. Yu, M.A. Jacobs, W.D. Salisbury, H. Enns, The effects of supply chain integration on customer satisfaction and financial performance: an organizational learning perspective, Int. J. Prod. Econ. 146 (1) (2013) 346–358.
[17] A. Al Tera, A. Alzubi, K. Iyiola, Supply chain digitalization and performance: a moderated mediation of supply chain visibility and supply chain survivability, Heliyon 10 (4) (2024).
[18] A. Asgari, Uncovering the role of big data analytics on the resilience of agri-food supply chains: a systematic literature review, Procedia Comput. Sci. 253 (2025) 1631–1639.
[19] A. Belhadi, S. Kamble, N. Subramanian, R.K. Singh, M. Venkatesh, Digital capabilities to manage agri-food supply chain uncertainties and build supply chain resilience during compounding geopolitical disruptions, Int. J. Oper. Prod. Manag. 44 (11) (2024) 1914–1950.
[20] T. Pal, K. Ganguly, A. Chaudhuri, Digitalisation in food supply chains to build resilience from disruptive events: a combined dynamic capabilities and knowledge-based view, Supply Chain Manag.: Int. J. 29 (6) (2024) 1042–1062.
[21] R.M. Grant, Toward a knowledge-based theory of the firm, Strateg. Manage J. 17 (S2) (1996) 109–122.
[22] M. Geissdoerfer, M.P. Pieroni, D.C. Pigosso, K. Soufani, Circular business models: a review, J. Clean. Prod. 277 (2020) 123741.
[23] B. Kogut, U. Zander, Knowledge of the firm, combinative capabilities, and the replication of technology, Organ. Sci. 3 (3) (1992) 383–397.
[24] J. Barney, Firm resources and sustained competitive advantage, J. Manage 17 (1) (1991) 99–120.
[25] J.B. Barney, Resource-based theories of competitive advantage: a ten-year retrospective on the resource-based view, J. Manage 27 (6) (2001) 643–650.
[26] D.J. Teece, G. Pisano, A. Shuen, Dynamic capabilities and strategic management, Strateg. Manage J. 18 (7) (1997) 509–533.
[27] I. Nonaka, H. Takeuchi, The knowledge-creating company: how Japanese companies create the dynamics of innovation, Long. Range Plann. 29 (4) (1996) 592.
[28] I. Nonaka, A dynamic theory of organizational knowledge creation, Organ. Sci. 5 (1) (1994) 14–37.
[29] Polanyi, M. (2009). *The tacit dimension, university of Chicago*.
[30] S. Šūmane, I. Kunda, K. Knickel, A. Strauss, T. Tisenkopfs, I. des Ios Rios, A. Ashkenazy, Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture, J. Rural. Stud. 59 (2018) 232–241.
[31] A. Agrawal, Dismantling the divide between indigenous and scientific knowledge, Dev. Change 26 (3) (1995) 413–439.
[32] F. Berkes, J. Colding, C. Folke, Rediscovery of traditional ecological knowledge as adaptive management, Ecol. Appl. 10 (5) (2000) 1251–1262.
[33] L. Klerkx, A. Proctor, Beyond fragmentation and disconnect: networks for knowledge exchange in the English land management advisory system, Land Use Policy 30 (1) (2013) 13–24.
[34] J.H. Dyer, K. Nobeoka, Creating and managing a high-performance knowledge-sharing network: the Toyota case, Strateg. Manage J. 21 (3) (2000) 345–367.
[35] G.T.M. Hult, D.J. Ketchen Jr, S.F Slater, Information processing, knowledge development, and strategic supply chain performance, Acad. Manag. J. 47 (2) (2004) 241–253.
[36] B.L. Simonin, An empirical investigation of the process of knowledge transfer in international strategic alliances, J. Int. Bus. Stud. 35 (2004) 407–427.
[37] R. Van Wijk, J.J. Jansen, M.A. Lyles, Inter-and intra-organizational knowledge transfer: a meta-analytic review and assessment of its antecedents and consequences, J. Manag. Stud. 45 (4) (2008) 830–853.
[38] N.J. Foss, S. Michailova (Eds.), Knowledge Governance: Processes and Perspectives, Oxford University Press, USA, 2009.
[39] R.B. Handfield, P.D. Cousins, B. Lawson, K.J. Petersen, How can supply management really improve performance? A knowledge-based model of alignment capabilities, J. Supply Chain Manag. 51 (3) (2015) 3–17.
[40] T. Khanna, Trust: Creating the Foundation For Entrepreneurship in Developing Countries, Berrett-Koehler Publishers, 2018.
[41] S. Wolfert, L. Ge, C. Verdouw, M.J. Bogaardt, Big data in smart farming–a review, Agric. Syst. 153 (2017) 69–80.
[42] W.M. Cohen, D.A. Levinthal, Absorptive capacity: a new perspective on learning and innovation, Adm. Sci. Q. 35 (1) (1990) 128–152.
[43] S.A. Zahra, G. George, Absorptive capacity: a review, reconceptualization, and extension, Acad. Manag. Rev. 27 (2) (2002) 185–203.
[44] A.P. Schotter, R. Mudambi, Y.L. Doz, A. Gaur, Boundary spanning in global organizations, J. Manag. Stud. 54 (4) (2017) 403–421.
[45] Z.J. Zhao, J. Anand, Beyond boundary spanners: the 'collective bridge'as an efficient interunit structure for transferring collective knowledge, Strateg. Manag. J. 34 (13) (2013) 1513–1530.
[46] P.R. Carlile, Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries, Organ. Sci. 15 (5) (2004) 555–568.
[47] C. Schmickl, A. Kieser, How much do specialists have to learn from each other when they jointly develop radical product innovations? Res. Policy 37 (3) (2008) 473–491.
[48] J. Ingram, Agricultural transition: niche and regime knowledge systems' boundary dynamics, Environ. Innov. Soc. Transit. 26 (2018) 117–135.
[49] L. Klerkx, C. Leeuwis, Balancing multiple interests: embedding innovation intermediation in the agricultural knowledge infrastructure, Technovation 28 (6) (2008) 364–378.
[50] M. Alavi, D.E. Leidner, Knowledge management and knowledge management systems: conceptual foundations and research issues, MIS Q. (2001) 107–136.
[51] A.H. Gold, A. Malhotra, A.H. Segars, Knowledge management: an organizational capabilities perspective, J. Manag. Inf. Syst. 18 (1) (2001) 185–214.
[52] D.A. Levinthal, J.G. March, The myopia of learning, Strateg. Manag. J. 14 (S2) (1993) 95–112.
[53] J.G. March, Exploration and exploitation in organizational learning, Organ. Sci. 2 (1) (1991) 71–87.
[54] R.B. Briner, D. Denyer, D.M. Rousseau, Evidence-based management: concept cleanup time? Acad. Manag. Perspect. 23 (4) (2009) 19–32.
[55] D.M. Rousseau, Is there such a thing as "evidence-based management"? Acad. Manag. Rev. 31 (2) (2006) 256–269.
[56] L. Klerkx, M. Schut, C. Leeuwis, C. Kilelu, Advances in knowledge brokering in the agricultural sector: towards innovation system facilitation, IDS Bull. 43 (5) (2012) 53–60.
[57] M. Schut, L. Klerkx, J. Rodenburg, J. Kayeke, L.C. Hinnou, C.M. Raboanarielina, L. Bastiaans, RAAIS: rapid appraisal of agricultural innovation systems (part i). A diagnostic tool for integrated analysis of complex problems and innovation capacity, Agric. Syst. 132 (2015) 1–11.
[58] G. Gereffi, J. Humphrey, T. Sturgeon, The governance of global value chains, Rev. Int. Polit. Econ. 12 (1) (2005) 78–104.
[59] J. Lee, G. Gereffi, J. Beauvais, Global value chains and agrifood standards: challenges and possibilities for smallholders in developing countries, Proc. Natl. Acad. Sci. 109 (31) (2012) 12326–12331.
[60] L. Dries, M. Gorton, V. Urutyan, J. White, Supply chain relationships, supplier support programmes and stimulating investment: evidence from the Armenian dairy sector, Supply Chain Manag.: Int. J. 19 (1) (2014) 98–107.
[61] C.W. Kilelu, L. Klerkx, C. Leeuwis, How dynamics of learning are linked to innovation support services: insights from a smallholder commercialization project in Kenya, J. Agric. Educ. Ext. 20 (2) (2014) 213–232.
[62] C.R. Carter, D.S. Rogers, A framework of sustainable supply chain management: moving toward new theory, Int. J. Phys. Distrib. Logist. Manag. 38 (5) (2008) 360–387.
[63] J. Elkington, Partnerships from cannibals with forks: the triple bottom line of 21st-century business, Environ. Qual. Manag. 8 (1) (1998) 37–51.
[64] M.A. Altieri, V.M. Toledo, The agroecological revolution in Latin America: rescuing nature, ensuring food sovereignty and empowering peasants, J. Peasant Stud. 38 (3) (2011) 587–612.
[65] J. Pretty, Agricultural sustainability: concepts, principles and evidence, Philos. Trans. R. Soc. B: Biol. Sci. 363 (1491) (2008) 447–465.
[66] D. Ivanov, A. Dolgui, Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak, Int. J. Prod. Res. 58 (10) (2020) 2904–2915.
[67] S.Y. Ponomarov, M.C. Holcomb, Understanding the concept of supply chain resilience, Int. J. Logist. Manag. 20 (1) (2009) 124–143.
[68] M. Christopher, H. Peck, Building the resilient supply chain, Int. J. Logist. Manag. 15 (2) (2004) 1–14.
[69] D.M. Tendall, J. Joerin, B. Kopainsky, P. Edwards, A. Shreck, Q.B. Le, J. Six, Food system resilience: defining the concept, Glob. Food Sec. 6 (2015) 17–23.
[70] M. Kamalahmadi, M.M. Parast, A review of the literature on the principles of enterprise and supply chain resilience: major findings and directions for future research, Int. J. Prod. Econ. 171 (2016) 116–133.

[71] A. Wieland, C.M. Wallenburg, The influence of relational competencies on supply chain resilience: a relational view, Int. J. Phys. Distrib. Logist. Manag. 43 (4) (2013) 300–320.
[72] M. Pagell, Z. Wu, Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars, J. Supply Chain Manag. 45 (2) (2009) 37–56.
[73] S. Seuring, M. Müller, From a literature review to a conceptual framework for sustainable supply chain management, J. Clean. Prod. 16 (15) (2008) 1699–1710.
[74] A.G. Power, Ecosystem services and agriculture: tradeoffs and synergies, Philos. Trans. R. Soc. B: Biol. Sci. 365 (1554) (2010) 2959–2971.
[75] M. Geissdoerfer, P. Savaget, N.M. Bocken, E.J. Hultink, The circular economy–a new sustainability paradigm? J. Clean. Prod. 143 (2017) 757–768.
[76] A. Murray, K. Skene, K. Haynes, The circular economy: an interdisciplinary exploration of the concept and application in a global context, J. Bus. Ethics 140 (2017) 369–380.
[77] T. Marsden, E. Smith, Ecological entrepreneurship: sustainable development in local communities through quality food production and local branding, Geoforum 36 (4) (2005) 440–451.
[78] Pereira, L., Bennett, E., Biggs, R., Peterson, G., McPhearson, T., Norström, A., … & Vervoort, J. (2018). Seeds of the future in the present: exploring pathways for navigating towards "Good" Anthropocenes.
[79] S. Bolwig, S. Ponte, A. Du Toit, L. Riisgaard, N. Halberg, Integrating poverty and environmental concerns into value-chain analysis: a conceptual framework, Dev. Policy Rev. 28 (2) (2010) 173–194.
[80] A. Devaux, M. Torero, J. Donovan, D. Horton, Agricultural innovation and inclusive value-chain development: a review, J. Agribus. Dev. Emerg. Econ. 8 (1) (2018) 99–123.
[81] C. Folke, T. Hahn, P. Olsson, J. Norberg, Adaptive governance of social-ecological systems, Annu Rev. Environ. Resour. 30 (1) (2005) 441–473.
[82] M.S. Reed, A.C. Evely, G. Cundill, I. Fazey, J. Glass, A. Laing, L.C. Stringer, What is social learning? Ecol. Soc. 15 (4) (2010).
[83] T. Hahn, F. Figge, J. Pinkse, L. Preuss, Trade-offs in corporate sustainability: you can't have your cake and eat it, Bus. Strategy Environ. 19 (4) (2010) 217–229.
[84] Z. Wu, M. Pagell, Balancing priorities: decision-making in sustainable supply chain management, J. Oper. Manag. 29 (6) (2011) 577–590.
[85] M. Porter, M. Kramer, Creating shared value, Harv. Bus. Rev. 89 (1/2) (2011) 62–77.
[86] S. Schaltegger, F. Lüdeke-Freund, E.G. Hansen, Business cases for sustainability: the role of business model innovation for corporate sustainability, Int. J. Innov. Sustain. Dev. 6 (2) (2012) 95–119.
[87] C.R. Binder, G. Feola, J.K. Steinberger, Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture, Environ. Impact Assess. Rev. 30 (2) (2010) 71–81.
[88] C. Schader, J. Grenz, M.S. Meier, M. Stolze, Scope and precision of sustainability assessment approaches to food systems, Ecol. Soc. 19 (3) (2014).
[89] M.P. Meuwissen, P.H. Feindt, A. Spiegel, C.J. Termeer, E. Mathijs, Y. De Mey, P. Reidsma, A framework to assess the resilience of farming systems, Agric. Syst. 176 (2019) 102656.
[90] L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda, NJAS-Wagening. J. Life Sci. 90 (2019) 100315.
[91] A. Walter, R. Finger, R. Huber, N. Buchmann, Smart farming is key to developing sustainable agriculture, Proc. Natl. Acad. Sci. 114 (24) (2017) 6148–6150.
[92] C.E. Helfat, R.S. Raubitschek, Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems, Res. Policy 47 (8) (2018) 1391–1399.
[93] P.C. Verhoef, T. Broekhuizen, Y. Bart, A. Bhattacharya, J.Q. Dong, N. Fabian, M. Haenlein, Digital transformation: a multidisciplinary reflection and research agenda, J. Bus. Res. 122 (2021) 889–901.
[94] C.N. Verdouw, J. Wolfert, A.J.M. Beulens, A. Rialland, Virtualization of food supply chains with the internet of things, J. Food Eng. 176 (2016) 128–136.
[95] H. Chen, R.H. Chiang, V.C. Storey, Business intelligence and analytics: from big data to big impact, MIS Q. (2012) 1165–1188.
[96] Y. Wang, L. Kung, T.A. Byrd, Big data analytics: understanding its capabilities and potential benefits for healthcare organizations, Technol. Forecast. Soc. Change 126 (2018) 3–13.
[97] O. Ahumada, J.R. Villalobos, Application of planning models in the agri-food supply chain: a review, Eur. J. Oper. Res. 196 (1) (2009) 1–20.
[98] D.C. Rose, W.J. Sutherland, C. Parker, M. Lobley, M. Winter, C. Morris, L.V. Dicks, Decision support tools for agriculture: towards effective design and delivery, Agric. Syst. 149 (2016) 165–174.
[99] Food and Agriculture Organization (FAO), Digital agriculture: transforming agriculture and food systems with digital technologies, Available online, https://openknowledge.fao.org/items/98a4c80a-b4d3-403c-8557-d8536c8316ee, 2022. access on 25 May 2025.
[100] N.M. Trendov, S. Varas, M. Zeng, Digital Technologies in Agriculture and Rural Areas, FAO, 2019.
[101] B.A. Aubert, A. Schroeder, J. Grimaudo, IT as enabler of sustainable farming: an empirical analysis of farmers' adoption decision of precision agriculture technology, Decis. Support. Syst. 54 (1) (2012) 510–520.
[102] J.C. Aker, I. Ghosh, J. Burrell, The promise (and pitfalls) of ICT for agriculture initiatives, Agric. Econ. 47 (S1) (2016) 35–48.
[103] U. Deichmann, A. Goyal, D. Mishra, Will digital technologies transform agriculture in developing countries? Agric. Econ. 47 (S1) (2016) 21–33.
[104] H. Baumüller, The little we know: an exploratory literature review on the utility of mobile phone-enabled services for smallholder farmers, J. Int. Dev. 30 (1) (2018) 134–154.
[105] N. Munthali, C. Leeuwis, A. van Paassen, R. Lie, R. Asare, R. van Lammeren, M. Schut, Innovation intermediation in a digital age: comparing public and private new-ICT platforms for agricultural extension in Ghana, NJAS-Wagening. J. Life Sci. 86 (2018) 64–76.
[106] K.S. Warner, M. Wäger, Building dynamic capabilities for digital transformation: an ongoing process of strategic renewal, Long Range Plann. 52 (3) (2019) 326–349.
[107] S. Wang, H. Zhang, Digital transformation and innovation performance in small- and medium-sized enterprises: a systems perspective on the interplay of digital adoption, digital drive, and digital culture, Systems 13 (1) (2025) 43, https://doi.org/10.3390/systems13010043 (Basel).
[108] S. Fainshmidt, A. Pezeshkan, M. Lance Frazier, A. Nair, E. Markowski, Dynamic capabilities and organizational performance: a meta-analytic evaluation and extension, J. Manag. Stud. 53 (8) (2016) 1348–1380.
[109] P.J. Lane, B.R. Koka, S. Pathak, The reification of absorptive capacity: a critical review and rejuvenation of the construct, Acad. Manag. Rev. 31 (4) (2006) 833–863.
[110] S. Ambulkar, J. Blackhurst, S. Grawe, Firm's resilience to supply chain disruptions: scale development and empirical examination, J. Oper. Manag. 33 (2015) 111–122.
[111] N. Altay, A. Gunasekaran, R. Dubey, S.J. Childe, Agility and resilience as antecedents of supply chain performance under moderating effects of organizational culture within the humanitarian setting: a dynamic capability view, Prod. Plan. Control 29 (14) (2018) 1158–1174.
[112] K. Scholten, P. Sharkey Scott, B. Fynes, Building routines for non-routine events: supply chain resilience learning mechanisms and their antecedents, Supply Chain Manag.: Int. J. 24 (3) (2019) 430–442.
[113] J. Ingram, Agronomist–farmer knowledge encounters: an analysis of knowledge exchange in the context of best management practices in England, Agric. Human Values 25 (2008) 405–418.
[114] J. Pretty, Intensification for redesigned and sustainable agricultural systems, Science (1979) 362 (6417) (2018) eaav0294.
[115] C. Lamine, Transition pathways towards a robust ecologization of agriculture and the need for system redesign. Cases from organic farming and IPM, J. Rural. Stud. 27 (2) (2011) 209–219.
[116] W. Zhang, T.H. Ricketts, C. Kremen, K. Carney, S.M. Swinton, Ecosystem services and dis-services to agriculture, Ecol. Econ. 64 (2) (2007) 253–260.
[117] A. Paloviita, Consumers' sustainability perceptions of the supply chain of locally produced food, Sustainability 2 (6) (2010) 1492–1509.
[118] A. Touboulic, H. Walker, Theories in sustainable supply chain management: a structured literature review, Int. J. Phys. Distrib. Logist. Manag. 45 (1/2) (2015) 16–42.
[119] S. Ponte, Greener than thou: the political economy of fish ecolabeling and its local manifestations in South Africa, World Dev. 36 (1) (2008) 159–175.
[120] L.T. Raynolds, D. Murray, A. Heller, Regulating sustainability in the coffee sector: a comparative analysis of third-party environmental and social certification initiatives, Agric. Human Values 24 (2007) 147–163.
[121] L. Fleming, Recombinant uncertainty in technological search, Manage Sci. 47 (1) (2001) 117–132.
[122] T. Savino, A. Messeni Petruzzelli, V. Albino, Search and recombination process to innovate: a review of the empirical evidence and a research agenda, Int. J. Manag. Rev. 19 (1) (2017) 54–75.
[123] R. Dubey, A. Gunasekaran, S.J. Childe, D. Roubaud, S.F. Wamba, M. Giannakis, C. Foropon, Big data analytics and organizational culture as complements to swift trust and collaborative performance in the humanitarian supply chain, Int. J. Prod. Econ. 210 (2019) 120–136.
[124] T.J. Pettit, K.L. Croxton, J. Fiksel, Ensuring supply chain resilience: development and implementation of an assessment tool, J. Bus. Logist. 34 (1) (2013) 46–76.
[125] K. Scholten, S. Schilder, The role of collaboration in supply chain resilience, Supply Chain Manag.: Int. J. 20 (4) (2015) 471–484.
[126] B.R. Tukamuhabwa, M. Stevenson, J. Busby, M. Zorzini, Supply chain resilience: definition, review and theoretical foundations for further study, Int. J. Prod. Res. 53 (18) (2015) 5592–5623.
[127] I. Ali, S. Nagalingam, B. Gurd, Building resilience in SMEs of perishable product supply chains: enablers, barriers and risks, Prod. Plan. Control 28 (15) (2017) 1236–1250.
[128] Rosset, P.M., & Altieri, M.A. (2017). *Agroecology: science and politics* (pp. 160–pp).
[129] P. Tittonell, Ecological intensification of agriculture—sustainable by nature, Curr. Opin. Environ. Sustain. 8 (2014) 53–61.
[130] M. Duru, O. Therond, G. Martin, R. Martin-Clouaire, M.A. Magne, E. Justes, J. P. Sarthou, How to implement biodiversity-based agriculture to enhance ecosystem services: a review, Agron. Sustain. Dev. 35 (2015) 1259–1281.
[131] S. Gliessman, Transforming food systems with agroecology, Agroecol. Sustain. Food Syst. 40 (3) (2016) 187–189.
[132] C. Gradl, B. Jenkins, Tackling Barriers to Scale: From Inclusive Business Models to Inclusive Business Ecosystems, CSR Initiative, Harvard Kennedy School, Cambridge, MA, 2011.
[133] S. Kelly, N. Vergara, H. Bammann, Inclusive Business Models, Food and Agriculture Organization of the United Nations, Rome, 2015.
[134] D. Dentoni, V. Bitzer, S. Pascucci, Cross-sector partnerships and the co-creation of dynamic capabilities for stakeholder orientation, J. Bus. Ethics 135 (2016) 35–53.

[135] E. Brandon-Jones, B. Squire, C.W. Autry, K.J. Petersen, A contingent resource-based perspective of supply chain resilience and robustness, J. Supply Chain Manag. 50 (3) (2014) 55–73.
[136] U. Jüttner, S. Maklan, Supply chain resilience in the global financial crisis: an empirical study, Supply Chain Manag.: Int. J. 16 (4) (2011) 246–259.
[137] I. Ali, I. Gölgeci, Where is supply chain resilience research heading? A systematic and co-occurrence analysis, Int. J. Phys. Distrib. Logist. Manag. 49 (8) (2019) 793–815.
[138] Y. Fan, M. Stevenson, A review of supply chain risk management: definition, theory, and research agenda, Int. J. Phys. Distrib. Logist. Manag. 48 (3) (2018) 205–230.
[139] B. Notarnicola, S. Sala, A. Anton, S.J. McLaren, E. Saouter, U. Sonesson, The role of life cycle assessment in supporting sustainable agri-food systems: a review of the challenges, J. Clean. Prod. 140 (2017) 399–409.
[140] P. Roy, D. Nei, T. Orikasa, Q. Xu, H. Okadome, N. Nakamura, T. Shiina, A review of life cycle assessment (LCA) on some food products, J. Food Eng. 90 (1) (2009) 1–10.
[141] K. Govindan, M. Hasanagic, A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective, Int. J. Prod. Res. 56 (1–2) (2018) 278–311.
[142] A. Jurgilevich, T. Birge, J. Kentala-Lehtonen, K. Korhonen-Kurki, J. Pietikäinen, L. Saikku, H. Schösler, Transition towards circular economy in the food system, Sustainability 8 (1) (2016) 69.
[143] L.T. Raynolds, Fair trade: social regulation in global food markets, J. Rural. Stud. 28 (3) (2012) 276–287.
[144] R. Ruben, R. Fort, The impact of fair trade certification for coffee farmers in Peru, World Dev. 40 (3) (2012) 570–582.
[145] G. Nemes, C. High, Old institutions, new challenges: the agricultural knowledge system in Hungary, Stud. Agric. Econ. 115 (2) (2013) 76–84.
[146] D. Fuchs, A. Kalfagianni, T. Havinga, Actors in private food governance: the legitimacy of retail standards and multistakeholder initiatives with civil society participation, Agric. Human Values 28 (2011) 353–367.
[147] J. Gupta, N.R. Pouw, M.A. Ros-Tonen, Towards an elaborated theory of inclusive development, Eur. J. Dev. Res. 27 (2015) 541–559.
[148] H. Tanriverdi, Information technology relatedness, knowledge management capability, and performance of multibusiness firms, MIS Q. (2005) 311–334.
[149] N. Roberts, V. Grover, Leveraging information technology infrastructure to facilitate a firm's customer agility and competitive activity: an empirical investigation, J. Manag. Inf. Syst. 28 (4) (2012) 231–270.
[150] C. Vitari, F. Pigni, DDGS affordances for value creation. Smart Organizations and Smart Artifacts: Fostering Interaction Between People, Technologies and Processes, Springer International Publishing, 2014, pp. 9–16.
[151] S. Bresciani, A. Ferraris, M. Del Giudice, The management of organizational ambidexterity through alliances in a new context of analysis: internet of things (IoT) smart city projects, Technol. Forecast. Soc. Change 136 (2018) 331–338.
[152] K. Trantopoulos, G. von Krogh, M.W. Wallin, M. Woerter, External knowledge and information technology, MIS Q. 41 (1) (2017) 287–300.
[153] Y. Duan, J.S. Edwards, Y.K. Dwivedi, Artificial intelligence for decision making in the era of big data–evolution, challenges and research agenda, Int. J. Inf. Manage 48 (2019) 63–71.
[154] N. Haefner, J. Wincent, V. Parida, O. Gassmann, Artificial intelligence and innovation management: a review, framework, and research agenda✰, Technol. Forecast. Soc. Change 162 (2021) 120392.
[155] A. Kamilaris, A. Kartakoullis, F.X. Prenafeta-Boldú, A review on the practice of big data analysis in agriculture, Comput. Electron. Agric. 143 (2017) 23–37.
[156] Tripoli, M., & Schmidhuber, J. (2018). Emerging opportunities for the application of blockchain in the agri-food industry.
[157] J.C. Aker, Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries, Agric. Econ. 42 (6) (2011) 631–647.
[158] J. F. Hair Jr, M. Sarstedt, L. Hopkins, V. G. Kuppelwieser, Partial least squares structural equation modeling (PLS-SEM) an emerging tool in business research, Eur. Bus. Rev. 26 (2) (2014) 106–121.
[159] L. Makhloufi, A.A. Laghouag, A. Ali Sahli, F. Belaid, Impact of entrepreneurial orientation on innovation capability: the mediating role of absorptive capability and organizational learning capabilities, Sustainability 13 (10) (2021) 5399.
[160] S. Cuéllar, M.T. Fernandez-Bajón, F. de Moya Anegón, A new approach to measure absorptive capacity and appropriability: a case of study in emerging markets, J. Knowl. Econ. 15 (3) (2024) 15418–15446.
[161] C. Xiong, Y. Wang, Z. Wu, F. Liu, What drives the development of digital rural life in China? Heliyon 10 (22) (2024) e39511.
[162] M.Y. El Mokadem, M.A. Khalaf, The contingent effect of supply chain strategies on the relationship between supply chain integration and operational performance in manufacturing context, J. Manuf. Technol. Manag. 34 (1) (2023) 147–164.
[163] M.M. Migdadi, Knowledge management processes, innovation capability and organizational performance, Int. J. Product. Perform. Manag. 71 (1) (2022) 182–210.
[164] R. Mrabet, Sustainable agriculture for food and nutritional security. Sustainable Agriculture and the Environment, Academic Press, 2023, pp. 25–90.
[165] R. Michel-Villarreal, E.L. Vilalta-Perdomo, M. Canavari, M. Hingley, Resilience and digitalization in short food supply chains: a case study approach, Sustainability 13 (11) (2021) 5913.
[166] S.A.R. Khan, A.A. Sheikh, I.R.A. Shamsi, Z. Yu, The implications of artificial intelligence for small and medium-sized enterprises' sustainable development in the areas of blockchain technology, supply chain resilience, and closed-loop supply chains, Sustainability 17 (1) (2025) 334.
[167] M.M.O. Pereira, M.E. Silva, L.C. Hendry, Supply chain sustainability learning: the COVID-19 impact on emerging economy suppliers, Supply Chain Manag.: Int. J. 26 (6) (2021) 715–736.
[168] W. Kabato, G.T. Getnet, T. Sinore, A. Nemeth, Z. Molnár, Towards climate-smart agriculture: strategies for sustainable agricultural production, food security, and greenhouse gas reduction, Agronomy 15 (3) (2025) 565.
[169] J.S. Armstrong, T.S. Overton, Estimating nonresponse bias in mail surveys, J. Mark. Res. 14 (3) (1977) 396–402.
[170] P. Guenther, M. Guenther, C.M. Ringle, G. Zaefarian, S. Cartwright, Improving PLS-SEM use for business marketing research, Ind. Mark. Manag. 111 (2023) 127–142.
[171] N. Kock, Common Method Bias: A Full Collinearity Assessment Method for PLS-SEM, in: H. Latan, R. Noonan (Eds.), Partial Least Squares Path Modeling: Basic Concepts, Methodological Issues and Applications, Springer, 2017, pp. 245–257. https://doi.org/10.1007/978-3-319-64069-3_11. Cham.
[172] Y. Dirgiatmo, Testing the discriminant validity and heterotrait–monotrait ratio of correlation (HTMT): a case in Indonesian SMEs. Macroeconomic Risk and Growth in the Southeast Asian Countries: Insight from Indonesia, Emerald Publishing Limited, 2023, pp. 157–170.
[173] F. Magno, F. Cassia, C.M. Ringle, A brief review of partial least squares structural equation modeling (PLS-SEM) use in quality management studies, TQM J. 36 (5) (2024) 1242–1251.
[174] G. Fassott, J. Henseler, P.S. Coelho, Testing moderating effects in PLS path models with composite variables, Ind. Manag. Data Syst. 116 (9) (2016) 1887–1900.
[175] G. Assaker, P. O'Connor, Using PLS-SEM to test for the moderation effects of continuous variables. hospitality and tourism studies, Cutting Edge Research Methods in Hospitality and Tourism, 2023, pp. 29–51, https://doi.org/10.1108/978-1-80455-063-220231003.
[176] S. Wang, H. Zhang, Green entrepreneurship success in the age of generative artificial intelligence: the interplay of technology adoption, knowledge management, and government support, Technol. Soc. 79 (2024) 102744, https://doi.org/10.1016/j.techsoc.2024.102744.