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Unlocking Digital Payoffs in Pharmaceutical Supply Chains: Organizational Learning Capability as a Boundary Condition

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ABSTRACT

Pharmaceutical supply chains operate under stringent regulatory regimes, temperature-sensitive logistics, and repeated threats of shortage and recall, conditions that render digital transformation key to reliability and efficiency of operations. This paper investigates whether supply chain digitalization enhances operational performance and whether organizational learning capability amplifies such impact in an emerging-economy setting. Grounded on the resource-based view and dynamic capabilities theory, we conceptualize supply chain digitalization as a portfolio of digital assets and process innovations and theorize organizational learning capability as a high-order capability for absorbing, assimilating, transforming, and applying knowledge encoded in digital traces. We test the model on survey data from the pharmaceutical supply chain sector of Jordan (n = 217) and estimate relationships by means of Partial Least Squares Structural Equation Modeling (PLS-SEM) with reflective indicators. The study found that supply chain digitalization positively and significantly impacts operational performance and that organizational learning capability positively moderates supply chain digitalization and operational performance interaction. Overall, results uncover digital investment paying faster, better, and more reliable speed, quality, and reliability when invested in learning architectures institutionalizing cross-functional knowledge flows and continuous improvement. The paper contributes by placing organizational learning capability in the role of a boundary-enforcing condition for realizing digitalization returns in regulated, high-reliability supply chains and by providing evidence from an under-investigated emerging-economy environment. Managerially, results highlight sequencing digitalization prompted by regulatory needs with operations redesign and investing in learning routines cultivating faith in data-driven and AI-based decision making.

Keywords: Supply Chain Digitalization, Operational Performance, Organizational Learning Capability, Emerging Economies, Pharmaceutical, Jordan
JEL Classification: L86, M11, O32, O33

1. INTRODUCTION

Digitalization has reshaped how supply chains sense, decide, and execute, with data-intensive tools such as IoT, advanced analytics, AI, blockchain, and automation, reconfiguring operational processes end-to-end (Queiroz et al., 2021). In regulated sectors such as pharmaceuticals, digital technologies are not merely efficiency enhancers; they are foundational to traceability, compliance, patient safety, and demand responsiveness (Ullagaddi, 2024). Yet organizations differ markedly in how well they convert digital investments into operational gains. Despite accelerating adoption of digital tools, evidence on how supply chain digitalization (SCD) translates into operational performance in pharmaceuticals remains fragmented. Studies document that SCD enhances resilience and performance through visibility, coordination, and faster recovery from disruptions (Zhao et al., 2023; Dubey et al., 2023; Huang et al., 2023), but sector-specific constraints, regulatory audits, serialization requirements, cold-chain integrity, and recall risks, complicate the digitalization–performance linkage. The field still lacks robust, context-sensitive evidence isolating SCD's direct effect on operational performance (OP) in pharma and clarifying (when) and (why) that effect is stronger, particularly in emerging markets where capability endowments and institutional supports differ (Melia et al., 2024; Miozza et al., 2024; Zaman et al., 2024).

Practically, pharma supply chains face rising exposure to shortages, falsified medicines, and volatile demand, which elevate the value of end-to-end traceability and data-driven coordination (Ma et al., 2022; Zakari et al., 2022; Sim et al., 2022). Theoretically, drawing on the resource-based view (RBV) and dynamic capabilities theory (DCT), digital tools constitute valuable, rare, and hard-to-imitate resource bundles that, when coupled with sensing-seizing-transforming routines, can yield superior operational outcomes (Queiroz et al., 2021; Govindan et al., 2022). However, RBV/DCT also imply that complementary capabilities, such as organizational learning capability (OLC), govern the conversion of digital inputs into operational outputs, suggesting moderation rather than uniform main effects. Thus this study, first, sector-specific syntheses highlight Pharma 4.0's promise but also adoption barriers and uneven performance payoffs (Saha et al., 2022). Second, while many studies emphasize mediation via resilience or capabilities (e.g., visibility, traceability), fewer test moderation by OLC (organizations' capacity to acquire, assimilate, transform, and apply knowledge) within pharma supply chains. Recent work across industries links learning-related capabilities to stronger innovation and performance effects of digitalization, but explicit tests of OLC as a boundary condition in pharma remain scarce (Otioma, 2023; Han et al., 2025). Third, evidence from emerging economies, where institutional voids and capability heterogeneity are salient, remains underrepresented despite the high stakes for medicine availability; regional analyses in the Middle East suggest knowledge practices underpin resilience, motivating a focused study in Jordan's pharmaceutical sector.

To address these gaps, we propose and empirically test a model in which SCD improves OP and OLC positively moderates the SCD–OP linkage. The study contributes by offering sector-specific evidence on the operational returns to SCD under stringent regulatory and compliance conditions; by integrating the resource-based view and dynamic capabilities theory with an OLC lens to explain why learning-rich firms convert digital tools into greater performance gains; and by providing evidence from an emerging-economy setting (Jordan's pharmaceutical industry) where capability building and institutional modernization are still unfolding.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1. Supply Chain Digitalization and Operational Performance

SCD refers to the pervasive embedding of digital technologies into inter-organizational processes to enable data capture, connectivity, analytics, and autonomous decision support across planning, sourcing, manufacturing, logistics, and service (Queiroz et al., 2021). Contemporary frameworks consistently emphasize a portfolio of mutually reinforcing technologies: Internet of Things (IoT) and RFID for sensing; cloud for connectivity; big data and advanced analytics for insight; artificial intelligence (AI) and machine learning for prediction and optimization; distributed ledger technologies/blockchain for provenance and immutability; and robotic process automation (RPA), digital twins, and cyber-physical systems for execution and simulation (Huang et al., 2023; Wamba et al., 2020; Konopik et al., 2022). These technologies do not yield value as isolated tools; rather, they cohere as capability bundles that enlarge information processing capacity, compress decision cycle times, and enable adaptive orchestration of supply networks (Queiroz et al., 2021; Konopik et al., 2022). In the pharmaceutical sector, SCD is not discretionary (Kannarkat et al., 2024). Serialized identification, end-to-end traceability, and tamper-evident data trails have become central to combat counterfeit medicines, protect patients, and satisfy increasingly stringent regulatory regimes (Sarkar, 2023).

Evidence shows blockchain-enabled traceability improves authenticity verification, recall responsiveness, and cold-chain monitoring, with live implementations (e.g., eZTracker) demonstrating real-time verification, interoperable multi-cloud deployment, and analytics for proactive risk management (Abu-Dabaseh et al., 2024; Sim et al., 2022). Recent empirical and review studies in pharma (Wong et al., 2023; Ghadge et al., 2023) report that digital traceability and analytics mitigate shortage risks, strengthen visibility, and improve operational continuity, while qualitative and practice-based work in health product supply chains corroborates the centrality of digital integration for resilience and service reliability (Yadav, 2024). At the same time, process studies of serialization indicate transitional productivity penalties at packaging lines, highlighting that digital compliance can initially depress overall equipment effectiveness (OEE) even as it enhances chain-level integrity, underscoring the need for complementary capability development (O'Mahony, 2024). Cross-industry quantitative research associates SCD with higher resilience and performance through mechanisms such as visibility, agility, and adaptive reconfiguration (Dubey et al., 2023; Huang et al., 2023; Zhao et al., 2023). Big data analytics capabilities in particular are shown to elevate agility/adaptability and downstream operational metrics (Mandal, 2019; Wamba et al., 2020), while reviews of digital SC management document robust performance pathways from sensing (IoT/RFID) to analytics to decision automation (Ferdousmou et al., 2024; Zhang et al., 2024). In regulated, high-reliability contexts such as pharma, these pathways converge on compliance-driven value (traceability, quality containment, recall speed) that is operationally consequential (Wong et al., 2023; Sim et al., 2022).

Operational performance is typically conceptualized as a multi-dimensional construct capturing efficiency (cost/productivity), delivery speed and reliability, flexibility, quality/service, and innovation/continuous improvement, often tailored to sectoral priorities (Alkhatib and Momani, 2023). In supply chains, OP reflects the extent to which processes transform inputs into outputs that meet customer/regulatory requirements while optimizing resource use (Masa'deh et al., 2022). Empirical work operationalizes OP using reflective indicators covering cost reduction, cycle time, inventory turns, delivery dependability, responsiveness, and defect/recall rates (Alkhatib and Momani, 2023). Pharmaceuticals face distinctive operational hazards: strict GMP compliance and auditability; serialization mandates; end-to-end cold-chain control for biologics and vaccines; and high-impact recall dynamics that tie quality failures to patient safety and brand risk (Wong et al., 2023; O'Mahony, 2024). Reviews of digitalization in pharma highlight that cold-chain temperature excursions and fragmented data are recurrent operational pain points; integrating IoT telemetry with interoperable traceability layers reduces waste and improves recall precision (Sim et al., 2022; Jiang et al., 2024). Post-pandemic analyses of falsified medicine regulations emphasize the burden placed on manufacturers, wholesalers, and dispensers but also document improved verification and patient protection (Melia et al., 2024). For emerging economies, institutional voids (e.g., uneven serialization mandates, fragmented logistics) increase variability and call for digital solutions that adapt to heterogeneous infrastructures (Ashiwaju et al., 2023; Yadav, 2024).

Robust quantitative studies evidence SCD's direct and indirect effects on OP. Zhao et al. (2023) uncover SCD enhances supply chain resilience, and supply chain resilience improves supply chain performance; Dubey et al. (2023) uncover dynamic digital capability components (digital adaptability and digital agility) play key roles in resilience results under turbulent conditions; and Huang et al. (2023) uncover Industry 4.0 adoption improves capability mediators of resilience and performance. Complementary evidence proposes large data analytics capability increases adaptability and agility, driving operational outcomes in turbulent conditions (Wang et al., 2024; Wamba et al., 2020). Pharmaceutical literature provides convergent support, with digital trace and analytics reducing deficiencies, improving supply chain coordination, and improving service dependability (Wong et al., 2023; Ghadge et al., 2023). From the resource-based view of the firm (RBV), digital platforms, information stocks, and analytics routines become valuable, rare, and hard-to-imitate resource bundles when embodied in firm-specific governance and processes (Huang et al., 2023; Wamba et al., 2020). The dynamic capabilities view of the firm (DCV) extends RBV by cataloging the use of sensing–seizing–reconfiguring routines for converting digital signals in operational process reconfiguration and rapid operational adjustments (Teece, 2018; Pitelis et al., 2024; Konopik et al., 2022). SCD thereby operates not just as a resource base but also as an enactor of high-order capabilities transforming environmental information into operational adjustments on a punctual basis; of special value in whitegoods markets like pharmaceutical supply chains, given sharp variation in pharma's cold-chain conditions, regulation, and demand. Hence, the hypothesis digital sensory/analytics and digital traceability reduce information latency and coordination failures and enable excellent_cost, speed, flexibility, and quality performance in regulated markets (Zhao et al., 2023; Wong et al., 2023). Pulling these results together, and applying logical necessity, we expect a positive main effect of SCD on OP in pharmaceutical supply chains:

H_1: Supply chain digitalization has a positive impact on operational performance.

2.2. The Moderating Role of Organizational Learning Capability

Organizational learning capability is the firm's ability of acquiring, diffusing/absorbing, transforming, and applying knowledge for the improvement of behavior and results (Haile and Tüzüner, 2022). Though measurement traditions have classic scales as antecedents, current literature ratifies four traditional dimensions (knowledge acquisition, assimilation/share, transformation, and application) and relates them to innovation, agility, and performance (Haile & Tüzüner, 2022; Han et al., 2025). The literature portrays OLC as a digital revolution-enabling meta-capability: aligning structures, driving experimentation, and linking mechanisms for speeding capability building feedback (Awad and Martín-Rojas, 2024; Konopik et al., 2022). Bibliometric syntheses also show sustained growth in learning–innovation research, with OLC repeatedly cited as a central antecedent of process innovation and ambidexterity (Hael et al., 2024). OLC as a lever for adaptability, sharing, and innovation. Empirical studies across contexts link higher OLC to faster assimilative learning, better cross-functional knowledge flows, and greater exploitation–exploration balance, which collectively foster operational adaptability and continuous improvement (Haile and Tüzüner, 2022; Xu et al., 2024). In supply chains, OLC catalyzes collaborative problem solving with partners, enabling "learning loops" around disruptions (e.g., shortages, recalls) and improving process innovation under regulatory constraints (Awad and Martín-Rojas, 2024). In emerging economies, where formal institutions and digital infrastructures are uneven, OLC compensates by leveraging informal coordination, experiential learning, and local knowledge to extract value from digital tools (Masa'deh et al., 2022).

Although SCD equips firms with data and tools, realizing operational gains requires the absorptive routines that interpret signals, reconfigure workflows, and institutionalize best practices. OLC therefore functions as a boundary condition that amplifies or muffles SCD's effect on OP. Recent empirical work shows learning-related capabilities strengthen links between digital/AI technologies and innovation/performance (Han et al., 2025), and digital transformation's effect on resilience is enhanced when learning and innovation routines are in place (Awad and Martín-Rojas, 2024). Conceptually, OLC fortifies the sensing (scanning and interpreting digital signals), seizing (experimenting and selecting options), and reconfiguring (codifying and scaling process changes) phases central to DCV (Teece, 2018; Pitelis et al., 2024; Konopik et al., 2022). In pharma supply chains, OLC should thus magnify SCD's operational benefits by accelerating the translation of serialisation/traceability data and IoT telemetry into corrective actions (e.g., targeted recalls, temperature-excursion containment) and continuous process improvement (Wong et al., 2023; Sim et al., 2022).

While most supply chain studies emphasize mediation (e.g., SCD - capabilities/resilience - performance), a smaller but growing stream tests moderation by learning/knowledge capabilities, finding stronger technology–performance effects in learning-rich firms (Han et al., 2025; Xu et al., 2024). Integrating RBV/DCV with the pharma context suggests a theoretically grounded model: SCD, as a bundle of digital resources and routines, directly raises OP by improving visibility, coordination, and error detection; OLC, as a meta-capability, strengthens this main effect by enabling absorptive, transformative learning that translates digital signals into improved operations (Salah and Alzghoul, 2024). The literature justifies testing both the direct SCD-OP link and the positive moderation by OLC, while recognizing sectoral idiosyncrasies such as serialization burdens and cold-chain risk. These arguments motivate the empirical framework advanced in this study. Analogous results appear in IT capability–agility relationships, where organizational learning positively moderates the effect of IT knowledge/operations on agility (Yi and Kim, 2025), suggesting generalizability of the logic to SCD–OP in pharma. Under high OLC, digital signals are more rapidly assimilated and acted upon, enhancing process reliability, speed, flexibility, and compliance; under low OLC, the same digital inputs may produce information overload, tool underutilization, or compliance-only adoption with weak operational payoffs (Han et al., 2025; Awad and Martín-Rojas, 2024). Accordingly, we propose:

H_2: Organizational learning capability positively moderates the relationship between supply chain digitalization and operational performance.

3. METHODOLOGY

3.1. Research Design and Context

This study adopts a quantitative, cross-sectional survey design suited to theory testing and generalizable inference about relationships among latent constructs modeled reflectively using Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is appropriate here given the study's prediction-oriented aims, the presence of a product-term interaction (moderation), and the expectation of non-normal indicators common in organizational surveys (Hair et al., 2019). The empirical context is the pharmaceutical industry in Jordan, an emerging-economy setting characterized by stringent regulatory requirements (Alzghoul et al., 2024). The target population comprised managerial and professional employees engaged in supply chain–related functions (planning, purchasing, manufacturing operations, quality/validation, warehousing, distribution, IT/digitalization) within Jordanian pharmaceutical manufacturers and their affiliated distribution/logistics units. A sampling frame was assembled from publicly available firm directories and professional networks. A total of 293 invitations were emailed to potential respondents using a personalized cover letter explaining the study purpose, confidentiality, and voluntary participation. After two reminders at 1-week intervals, 224 responses were received; following data screening, 217 valid questionnaires remained for analysis. Such a sample size exceeds common guidelines for PLS-SEM and provides adequate statistical power to detect theoretically meaningful effects, including interaction terms, under small-to-moderate effect-size assumptions (Hair et al., 2019).

3.2. Instrument Development and Measures

All focal constructs were modeled as reflective. Items were presented on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree), randomized within sections to reduce response patterns. Supply Chain Digitalization (SCD): the study adapted indicators reflecting the breadth and depth of digital technology deployment in supply chain processes. 7 Items were derived from Kache and Seuring (2017) and aligned with the SCD conceptualization and operationalizations in Zhao et al. (2023). Example item stems include "*Our supply chain uses digital technologies to track materials and products in real time*" and "*Advanced analytics/AI are used to support planning and execution decisions*". Organizational Learning Capability (OLC): with 9 items, the study employed the widely used OLC scale capturing knowledge acquisition, dissemination/assimilation, transformation, and application (Chiva et al., 2007). Example items include "*Ideas are frequently communicated across departments*" and "*The organization systematically reviews failures to improve processes*". Operational Performance (OP): it was conceptualized as efficiency, responsiveness, quality/reliability, and flexibility outcomes in the supply chain. 6 Items were adapted from Li et al. (2006), with wording tailored to pharmaceutical operations (e.g., delivery dependability, cycle-time improvements, defect/recall containment, cost productivity).

After finalizing the questionnaire, we conducted a structured Arabic translation and linguistic validation. A review panel comprising two academic experts (operations management and supply chain analytics) and three senior industry practitioners (quality assurance, logistics, and digitalization leads) assessed the instrument for clarity, relevance, and sector-specific appropriateness. Their feedback led to minor wording refinements to align usage with pharmaceutical terminology (e.g., serialization, cold chain). For items intended for bilingual administration, we implemented a committee-based forward–backward translation protocol with reconciliation to ensure semantic equivalence and conceptual fidelity across languages. A pilot with 15 respondents from the target population assessed clarity, time burden, and preliminary reliability; feedback led to modest refinements (e.g., examples added to certain items, removal of ambiguous phrasing). Pilot responses were excluded from the final analysis.

4. ANALYSIS

In this section, we report on the empirical results of our variance-based structural equation modeling using partial least squares (PLS-SEM), which we employed to estimate the hypothesized paths and the moderating effect. Following best-practice sequencing, we first assess the measurement models, examining indicator reliability, internal consistency (composite reliability), convergent validity (average variance extracted) and factor loading.

Table 1 indicates reliable and convergent valid measures, suitable for proceeding to discriminant-validity and structural-model assessments. The reflective measures show sound quality. Internal consistency is strong for all constructs (Cronbach's α: SCD = 0.883; OLC = 0.879; OP = 0.909), and composite reliability exceeds the commonly recommended 0.70 benchmark (SCD = 0.91; OLC = 0.90; OP = 0.93). Convergent validity is supported, with AVE values at or above the 0.50 threshold (SCD = 0.557; OLC = 0.501; OP = 0.608). At the indicator level, loadings cluster in acceptable ranges: SCD items span 0.618–0.842, OLC items 0.625–0.772, and OP items 0.695–0.887. A few indicators fall modestly below 0.70 (e.g., SCD2 = 0.674; SCD3 = 0.618; two OLC items around 0.63–0.69; FP5 = 0.695), but their retention is defensible because construct-level reliability and AVE meet criteria, and these items help preserve content coverage (Fornell and Larcker, 1981; Hair and Alamer, 2022).

The HTMT ratios indicate that the three latent constructs are empirically distinct as Table 2. All pairwise HTMT values fall comfortably below the conservative 0.85 benchmark (SCD–OP = 0.684, SCD–OLC = 0.612, and OLC–OP = 0.571) suggesting that each construct shares more variance with its own indicators than with those of the others and that construct overlap is unlikely to bias the structural estimates. Even under the more liberal 0.90 guideline sometimes used for conceptually proximate constructs, the evidence would remain unequivocally supportive (Henseler et al., 2015; Voorhees et al., 2016). Taken together, these results satisfy contemporary recommendations for discriminant validity in variance-based SEM and justify proceeding to the structural model assessment.

In Table 3 the structural estimates show a clear and practically meaningful link between supply-chain digitalization and operational performance. The direct path from SCD to OP is positive and precise ($\beta = 0.421$, SE = 0.058, t = 7.259, P = 0.001), and its 95% percentile-bootstrap confidence interval excludes zero [0.309, 0.531]. The corresponding effect size ($f^2 = 0.181$) falls in the "medium" range, indicating that digitalization contributes materially to explaining differences in operational outcomes across firms. Substantively, these results suggest that organizations investing in digital supply-chain capabilities, such as integrated data flows, process automation, and real-time visibility, tend to realize tangible gains in efficiency and reliability. On this basis, H1 is supported. The moderating term (SCD × OLC → OP) is also positive and statistically reliable ($\beta = 0.211$, SE = 0.061, t = 3.459, P = 0.001; 95% CI [0.093, 0.328]). Although its effect size is modest ($f^2 = 0.072$), the sign and precision indicate that stronger organizational learning capability enhances the performance returns to digitalization rather than replacing them. In practical terms, firms with robust routines for knowledge acquisition, dissemination, and use convert digital investments into superior operational execution more effectively, the slope of SCD → OP is steeper at higher levels of OLC. Accordingly, H2 is supported.

Table 1: Factor loadings, construct reliability, and convergent validity

Construct	Item	Factor loadings	Cα	CR	AVE
Supply Chain Digitalization	SCD1	0.842	0.883	0.91	0.557
	SCD2	0.674			
	SCD3	0.618			
	SCD4	0.763			
	SCD5	0.754			
	SCD6	0.733			
	SCD7	0.816			
Organizational Learning Capability	OLC1	0.721	0.879	0.90	0.501
	OLC2	0.694			
	OLC3	0.625			
	OLC4	0.744			
	OLC5	0.772			
	OLC6	0.748			
	OLC7	0.771			
	OLC8	0.769			
	OLC9	0.705			
Operational Performance	OP1	0.728	0.909	0.93	0.608
	OP2	0.806			
	OP3	0.887			
	OP4	0.752			
	OP5	0.695			
	OP6	0.794			

Table 2: Discriminant validity using HTMT ratios

Constructs	1	2	3
1. Supply Chain Digitalization	-		
2. Org Learning Capability	0.612	-	
3. Operational performance	0.684	0.571	-

Values below the diagonal are Heterotrait-monotrait (HTMT) ratios

5. DISCUSSION

This study set out to examine how SCD shapes OP in pharmaceutical firms and whether OLC conditions this relationship. In an emerging economy such as Jordan, where pharmaceutical manufacturing and distribution operate under tight regulatory scrutiny, demand volatility, and infrastructure constraints, the promise of digital technologies is particularly salient for improving speed, quality, compliance, and cost-efficiency. The positive SCD-OP effect aligns with the dynamic capabilities view (DCV), which posits that digitally enabled sensing, seizing, and reconfiguring routines allow firms to convert data and connectivity into operational efficiency, responsiveness, and quality outcomes (Teece, 2018; Pitelis et al., 2024). In pharmaceutical supply chains, digitalization improves batch genealogy, end-to-end visibility, demand-sensing, deviation management, and release-cycle time, capabilities tightly coupled with compliance and patient safety. Recent empirical studies corroborate these performance gains. For example, Zhao et al. (2023) show that digitalization improves supply chain performance via resilience-building mechanisms, a pattern echoed by Dubey et al. (2023), who further highlight the role of complementary institutional enablers. Evidence from manufacturing and operations research similarly links big data analytics and Industry 4.0 toolsets to agility, adaptability, and cost-quality improvements (Wamba et al., 2020; Wong et al., 2023). Collectively, our H1 result is consistent with the argument that digital infrastructures and analytics pipelines translate into

Table 3: Direct and moderating effects

Path	β	SD	t-value	P-value	f^2	Percentile bootstrap	
						2.5%	97.5%
Direct effects							
SCD - > OP	0.421	0.058	7.259	0.001	0.181	0.309	0.531
Moderating effect							
SCD*OLC - > OP	0.211	0.061	3.459	0.001	0.072	0.093	0.328

B: Beta value, SD: Standard deviation, f^2: Cohen's effect size, 2.5%: Lower bound confidence interval, 97.5%: Upper bound confidence interval leaner, faster, and more reliable pharmaceutical operations when embedded in appropriate processes and governance.

On the other hand, the study find that OLC positively moderates the SCD-OP connection, those firms having more potential for knowledge acquisition, assimilation, transformation, and application have more operational value from digital investments. The relationship is in accord with literature posing organizational and digital capabilities as complements of each other; OLC underpins the micro foundations for enabling firms to learn from data, iterate standard operating procedures, and institutionalize process improvements (Konopik et al., 2022). Studies on other fields of operations and innovation also find that learning mechanisms condition performance payoffs from AI, analytics, and digital instruments (e.g., Wamba et al., 2020; Han et al., 2025). In short, digitalization offers the "means," and OLC offers the absorptive and adaptive "muscle" that makes signals into routines, and routines into operational advantage. Despite our significant modulation, sector conditions suggest conditions under which amplifying role of OLC fades. Firstly, digitalization spurred by requirements of compliances (e.g., serialization for averting falsified medicates) adds new steps, bottlenecks, and capital expenditure whose efficiency dampening ripples do not subside for some time regardless of strength of learning. Recent reports of Europe circumstances include larger numbers of line downtime and overall equipment effectiveness lowered following serialization, side by side with new docs-burden of documentation (O'Mahony, 2024; Melia et al., 2024). In such circumstances, otherwise high-OLC players might struggle to convert digital mandates short term into efficiency advantages; impact of the OLC might reveal itself more on more prolonged stabilization phases. Secondly, digital maturity and quality of data might play role of constraints. When the data are fragmented, weakly governed by master-data, cold-chain IoT telemetry is incomplete, the loop of learning has weak inputs on which to act; payoff of OLC is blunted. Health-product supply lines, especially in resource-challenged contexts, suffer from uneven digitization of upstream of public and private nodes; without interoperable data and governance, marginal return of applying OLC is decreased (Yadav, 2024).

Similarly, where cyber-infrastructure or ERP backbones are brittle, OLC's ability to translate insights into reliable execution is constrained. Third, structural load of regulatory and quality systems can dominate variance in OP. In highly validated environments (GMP, GxP), performance is bounded by qualification/validation cycles, change-control lead times, and QA review workloads. Under such constraints, the incremental effect of learning on the SCD-OP path may be statistically small in short windows, even though learning remains vital for continuous improvement. Evidence from pharmaceutical digital-risk work indicates that digital tools reduce shortage risk and improve traceability, but the operational benefits may be mediated through risk and compliance channels before manifesting in classical OP metrics (Wong et al., 2023).

In emerging markets, our findings emphasize that capability complementarity matters. The Jordanian manufacturing sector is exposed to diversified supplier quality, inconsistent informational standards, and financing constraints that characterize digital adoption behaviors. Empirical writings on Jordanian manufacturing reveal technology management and technology integration as notable predictors of performance in operations (Masa'deh et al., 2022). Industry-oriented analysis in Middle Eastern pharmaceutical markets identifies knowledge management and learning routines as primary drivers of resilience and performance in the face of disruption (Zighan et al., 2024). Conjointly, these inform our tale of moderation: without well-developed digital sites of infrastructure, OLC supports localizing, routinizing, and scaling digital work at plants and distribution centers and, thereby, enhances the SCD-OP payoff. Institutional contingencies like those outlined by Dubey et al. (2023) for government effectiveness, for example, in bridging digital capability and resilience dilute short-run impacts. By extension, such institutional facilitation likely moderates the extent of OLC's moderation in emerging markets. Middle Eastern case-based analysis on digital collaboration and analytics capability in Jordan proposes similar patterns where system-level enablers like partner connectivity and common analytics impact performance by way of resilience routes (Alshawabkeh et al., 2024).

6. CONCLUSION

The paper investigated how SCD builds OP in pharmaceutical firms and whether OLC conditions that act in an emerging-economy environment. By extending the resource-based view and dynamic capabilities theory, we argued that digital technologies consist of pools of resources that buttress sensing, coordination, and execution. In parallel, we hypothesized OLC as a meta-capability facilitating institutions to accumulate, assimilate, transform, and transfer knowledge enshrined in digital signals. Theoretically, the findings Mature DCV assertions by outlining OLC as a boundary-enforcing condition that converts digital inputs into sustainable process improvements, especially in compliance-intensive, high-reliability supply chains such as pharmaceuticals. Operationally, managers must approach digitalization and learning architecture as complements. Returns on digital traceability, analytics, and AI arise when firms institutionalize learning loops (after-action reviews; cross-functional problem-solving; SOP iteration; capability building in data and GMP-aware digital workflows) that translate information into operational action. The moderation argument also rationalizes mixed findings in the literature: wherever regulatory load is severe, the data infrastructure is fractured, or master-data governance is weak, return on SCD may be latent or mediated by resilience/compliance before arising in classical OP measures.

For emerging economies, the study highlights the role of OLC in compensating for uneven ecosystem maturity by enabling firms to localize, routinize, and scale digital practices across manufacturing and distribution nodes. Policy makers can amplify firm-level learning effects by supporting interoperable data standards, secure public–private data sharing, and workforce upskilling in digital quality and cold-chain management. Limitations suggest avenues for refinement. Our cross-sectional design cannot adjudicate temporal sequencing; longitudinal or panel designs could trace capability formation and payoff lags. Self-report measures, while common in organizational research, may be complemented by objective indicators (OEE, recall precision, cold-chain excursion rates). Future research should compare sectors with varying regulatory burdens, examine cross-country differences in institutional scaffolds, study multi-tier supply networks with partner-level learning heterogeneity, and integrate multi-method approaches (e.g., machine logs, archival quality data, and qualitative process tracing). Overall, the evidence advances a nuanced capability-complementarity view: digitalization raises operational performance, and organizations that learn better, perform better, especially when operating under the exacting demands of pharmaceutical supply chains.

REFERENCES

Abu-Dabaseh, F., Alghizzawi, M., Alkhlaifat, B.I., Ezmigna, A.A.R., Alzghoul, A., AlSokkar, A.A., Al-Gasawneh, J. (2024), Enhancing Privacy and Security in Decentralized Social Systems: Blockchain-Based Approach. In: 2024 2nd International Conference on Cyber Resilience (ICCR). IEEE. p1-6.

Alkhatib, S.F., Momani, R.A. (2023), Supply chain resilience and operational performance: The role of digital technologies in Jordanian manufacturing firms. Administrative Sciences, 13(2), 40.

Alshawabkeh, R.O., Abu Rumman, A.R., Al-Abbadi, L.H. (2024), The nexus between digital collaboration, analytics capability and supply chain resilience of the food processing industry in Jordan. Cogent Business and Management, 11(1), 2296608.

Alzghoul, A., Aboalganam, K.M., Al-Kasasbeh, O. (2024), Nexus among green marketing practice, leadership commitment, environmental consciousness, and environmental performance in Jordanian pharmaceutical sector. Cogent Business and Management, 11(1), 2292308.

Ashiwaju, B.I., Agho, M.O., Okogwu, C., Orikpete, O.F., Daraojimba, C. (2023), Digital transformation in pharmaceutical supply chain: An African case. Matrix Science Pharma, 7(3), 95-102.

Awad, J.A., Martín-Rojas, R. (2024), Digital transformation influence on organisational resilience through organisational learning and innovation. Journal of Innovation and Entrepreneurship, 13(1), 69.

Chiva, R., Alegre, J., Lapiedra, R. (2007), Measuring organisational learning capability among the workforce. International Journal of Manpower, 28(3/4), 224-242.

Dubey, R., Bryde, D.J., Dwivedi, Y.K., Graham, G., Foropon, C., Papadopoulos, T. (2023), Dynamic digital capabilities and supply chain resilience: The role of government effectiveness. International Journal of Production Economics, 258, 108790.

Ferdousmou, J., Prabha, M., Farouk, M.O., Samiun, M.D., Sozib, H.M., Zaman, A.M. (2024), IoT-enabled RFID in supply chain management: A comprehensive survey and future directions. Journal of Computer and Communications, 12(11), 207-223.

Fornell, C., Larcker, D.F. (1981), Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1), 39-50.

Ghadge, A., Bourlakis, M., Kamble, S., Seuring, S. (2023), Blockchain implementation in pharmaceutical supply chains: A review and conceptual framework. International Journal of Production Research, 61(19), 6633-6651.

Govindan, K., Kannan, D., Jørgensen, T.B., Nielsen, T.S. (2022), Supply Chain 4.0 performance measurement: A systematic literature review, framework development, and empirical evidence. Transportation Research Part E: Logistics and Transportation Review, 164, 102725.

Hael, M., Belhaj, F. A., & Zhang, H. (2024). Organizational learning and innovation: A bibliometric analysis and future research agenda. Heliyon, 10(11), e31812.

Haile, E. A., & Tüzüner, V. L. (2022). Organizational learning capability and its impact on organizational innovation. Asia Pacific Journal of Innovation and Entrepreneurship, 16(1), 69-85.

Hair, J., Alamer, A. (2022), Partial least squares structural equation modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. Research Methods in Applied Linguistics, 1(3), 100027.

Hair, J.F., Risher, J.J., Sarstedt, M., Ringle, C.M. (2019), When to use and how to report the results of PLS-SEM. European Business Review, 31(1), 2-24.

Han, S., Zhang, D., Zhang, H., Lin, S. (2025), Artificial intelligence technology, organizational learning capability, and corporate innovation performance: Evidence from Chinese specialized, refined, unique, and innovative enterprises. Sustainability, 17(6), 2510.

Henseler, J., Ringle, C.M., Sarstedt, M. (2015), A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43(1), 115-135.

Huang, K., Wang, K., Lee, P.K., Yeung, A.C. (2023), The impact of industry 4.0 on supply chain capability and supply chain resilience: A dynamic resource-based view. International Journal of Production Economics, 262, 108913.

Jiang, S., Jia, S., Guo, H. (2024), Internet of Things (IoT)-enabled framework for a sustainable vaccine cold chain management system. Heliyon, 10(7), e28910.

Kache, F., Seuring, S. (2017), Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. International Journal of Operations and Production Management, 37(1), 10-36.

Kannarkat, J.T., Denham, M.W., Sarpatwari, A. (2024), Improving drug supply chain security. JAMA Health Forum, 5(1), e234819-e234819.

Konopik, J., Jahn, C., Schuster, T., Hoßbach, N., Pflaum, A. (2022), Mastering the digital transformation through organizational capabilities: A conceptual framework. Digital Business, 2(2), 100019.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T.S., Rao, S.S. (2006), The impact of supply chain management practices on competitive advantage and organizational performance. Omega, 34(2), 107-124.

Ma, J.Y., Shi, L., Kang, T.W. (2022), The effect of digital transformation on the pharmaceutical sustainable supply chain performance: The mediating role of information sharing and traceability using structural equation modeling. Sustainability, 15(1), 649.

Mandal, S. (2019), The influence of big data analytics management capabilities on supply chain preparedness, alertness and agility: An empirical investigation. Information Technology and People, 32(2), 297-318.

Masa'deh, R.E., Muheisen, I., Obeidat, B., Bany Mohammad, A. (2022), The impact of supply chain integration on operational performance: An empirical study. Sustainability, 14(24), 16634.

Melia, E., English, A., Naughton, B.D. (2024), The impact of global falsified medicines regulation on healthcare stakeholders in the legitimate pharmaceutical supply chain: A systematic review. Frontiers in Medicine, 11, 1429872.

Miozza, M., Brunetta, F., Appio, F.P. (2024), Digital transformation of the Pharmaceutical Industry: A future research agenda for management studies. Technological Forecasting and Social Change, 207, 123580.

O'Mahony, D., Lynch, A., McDermott, O. (2024), The impact of serialisation on operational efficiency and productivity in Irish pharmaceutical sites. Therapeutic Innovation and Regulatory Science, 58(5), 883-896.

Otioma, C. (2023), IT capability, organisational learning and innovation performance of firms in Kenya. Journal of the Knowledge Economy, 14(3), 3489-3517.

Pitelis, C.N., Teece, D.J., Yang, H. (2024), Dynamic capabilities and

MNE global strategy: A systematic literature review-based novel conceptual framework. Journal of Management Studies, 61(7), 3295-3326.

Queiroz, M.M., Pereira, S.C.F., Telles, R., Machado, M.C. (2021), Industry 4.0 and digital supply chain capabilities: A framework for understanding digitalisation challenges and opportunities. Benchmarking: An International Journal, 28(5), 1761-1782.

Saha, E., Rathore, P., Parida, R., Rana, N.P. (2022), The interplay of emerging technologies in pharmaceutical supply chain performance: An empirical investigation for the rise of Pharma 4.0. Technological Forecasting and Social Change, 181, 121768.

Salah, A.H., Alzghoul, A. (2024), Assessing the moderating role of customer orientation on the impact of business intelligence tools on digital marketing strategy optimization. International Review of Management and Marketing, 14(3), 18.

Sarkar, S. (2023), Why pharmaceutical drug traceability in the US needs a centralized cloud-based platform. Current Journal of Applied Science and Technology, 42(21), 1-11.

Sim, C., Zhang, H., Chang, M.L. (2022), Improving end-to-end traceability and pharma supply chain resilience using blockchain. Blockchain in Healthcare Today, 5, 10-30953.

Teece, D.J. (2018), Business models and dynamic capabilities. Long Range Planning, 51(1), 40-49.

Ullagaddi, P. (2024), Leveraging digital transformation for enhanced risk mitigation and compliance in pharma manufacturing. Journal of Advances in Medical and Pharmaceutical Sciences, 26(6), 75-86.

Voorhees, C.M., Brady, M.K., Calantone, R., Ramirez, E. (2016), Discriminant validity testing in marketing: An analysis, causes for concern, and proposed remedies. Journal of the Academy of Marketing Science, 44(1), 119-134.

Wamba, S.F., Dubey, R., Gunasekaran, A., Akter, S. (2020), The performance effects of big data analytics and supply chain ambidexterity: The moderating effect of environmental dynamism. International Journal of Production Economics, 222, 107498.

Wang, Y., Qian, X., & Fang, C. (2024). Deconstructing supply chain resilience under big data analytics capability: Exploring the mediating and moderating roles of agility and top management participation. In E. Y. Li et al. (Eds.), Proceedings of the International Conference on Electronic Business (Vol. 24, pp. 108–121). ICEB ’24, Zhuhai, China, October 24–28, 2024.

Wong, W.P., Saw, P.S., Jomthanachai, S., Wang, L.S., Ong, H.F., Lim, C.P. (2023), Digitalization enhancement in the pharmaceutical supply network using a supply chain risk management approach. Scientific Reports, 13(1), 22287.

Xu, M., Zhang, Y., Sun, H., Tang, Y., Li, J. (2024), How digital transformation enhances corporate innovation performance: The mediating roles of big data capabilities and organizational agility. Heliyon, 10(14), e34905.

Yadav, P. (2024), Digital transformation in the health product supply chain: A framework for analysis. Health Systems and Reform, 10(2), 2386041.

Yi, W., Kim, S. (2025), The impact of IT capabilities on organizational agility with the moderating effect of organizational learning. IEEE Access, 13, 30915-30935.

Zakari, N., Al-Razgan, M., Alsaadi, A., Alshareef, H., Alashaikh, L., Alharbi, M., Alomar, R., Alotaibi, S. (2022), Blockchain technology in the pharmaceutical industry: A systematic review. PeerJ Computer Science, 8, e840.

Zaman, A., Jerin, I., Ghosh, P., Akther, A., Shrity, S.S., Sarwar, F. (2024), A hierarchical multi-criteria model for analyzing the barriers to Pharma 4.0 implementation in developing countries. Healthcare Analytics, 5, 100334.

Zhang, H., Lv, Y., Zhang, S., Liu, Y.D. (2024), Digital supply chain management: A review and bibliometric analysis. Journal of Global Information Management (JGIM), 32(1), 1-20.

Zhao, N., Hong, J., Lau, K.H. (2023), Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. International Journal of Production Economics, 259, 108817.

Zighan, S., Dwaikat, N.Y., Alkalha, Z., Abualqumboz, M. (2024), Knowledge management for supply chain resilience in pharmaceutical industry: Evidence from the Middle East region. The International Journal of Logistics Management, 35(4), 1142-1167.