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IDENTIFYING THE ROLE OF DIGITALIZATION ON SUPPLY CHAIN PERFORMANCE IN THE POST-COVID-19 ERA: THE MEDIATION EFFECT OF SUPPLY CHAIN EFFICIENCY AND INTEGRATION

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KEYWORDS

PLS-SEM, Emerging Economies, Supply Chain Digitalisation, Supply Chain Resilience, Supply Chain Integration, Dynamic Capabilities View.

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ABSTRACT

This study examines how Supply Chain Digitalisation (DGT) affects Supply Chain Performance (SCP) in the extremely unstable post-COVID-19 manufacturing sector of Karachi, Pakistan. Based on the Resource-Based View (RBV) and Dynamic Capabilities View (DCV), the study fills a significant theoretical gap by assessing the moderating boundary conditions of Supply Chain Dynamism (SCD) and Supply Chain Resilience (SCR), as well as the mediating roles of Supply Chain Integration (SCIS) and Supply Chain Efficiency (SCE). A purposive sample of 159 supply chain and operations personnel from formal, medium-to-large-scale manufacturing companies was used in this quantitative, cross-sectional study. PLS-SEM, or partial least squares structural equation modelling, was used to analyse the data using SmartPLS. The empirical findings reveal that while DGT directly and significantly enhances SCP, SCIS and SCE, traditional lean paradigms fail under continuous macro-level disruptions. Specifically, SCIS and SCE exhibited negative direct impacts on performance, demonstrating that rigid single-source integration and hyper-efficiency (e.g., zero safety stock) transform into systemic vulnerabilities during continuous macroeconomic crises. Furthermore, while high market dynamism amplifies the value of digital tools in fostering integration, SCR was found to negatively moderate the DGT-SCP relationship. This novel finding exposes a critical "resource allocation trade-off" in capital-constrained environments, where attempting to simultaneously fund expensive digital infrastructures and heavy physical resilience buffers drains working capital and diminishes optimal performance. The study concludes that manufacturing executives in emerging economies must pivot from absolute lean optimization to agile adaptability by strategically de-integrating and carefully balancing technological investments with moderate physical buffers to ensure operational survival.

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Introduction

In today's business world, Supply Chain Management (SCM) has evolved from a mere support role to a critical capability for survival and competitiveness. Companies have pursued lean and agile supply networks to reduce expenses and achieve supply chain integration. Nevertheless, firms and researchers have encountered significant supply chain interruptions brought on by the COVID-19 pandemic, geopolitical disputes and severe weather (Ivanov, 2020; Farrukh & Sajjad, 2025). Organizations faced unprecedented challenges and downsizing processes while adjusting to new realities. The key research question changed from how to make supply networks more integrated and efficient to how to make them more resilient (Salamah et al., 2024; Zaheer, 2026). In particular, two innovative concepts of Supply Chain Digitalisation (DGT) and Supply Chain Resilience (SCR) have gained considerable attention (Ivanov, 2021; Salamah et al., 2024; Zaheer, 2026).

The Internet of Things (IoT), artificial intelligence (AI) and big data are examples of Industry 4.0 technologies that have been integrated into supply chains to digitise and speed up the movement of money, goods and information. (Bin Ahmed & Hashim, 2026). Supply chain digitalisation refers to the design and implementation of digitized processes in end-to-end supply networks. Dynamic Capabilities View (DCV) of the firm defines dynamic abilities as "high-level transient competencies that underpin firms' core competencies and ongoing development process and purposeful, emergent and enduring competencies that provide superior market insights, foster value capture and promote organizational renewal" (Teece et al., 1997, p. 123). From DCV perspective, digitalization of supply chains is one key dynamic capability in firm's efforts to achieve resilience.

However, collection of works of literature demonstrates the connection between technology-based interventions and supply chain outcomes is far from being direct or linear. In most cases, technology-enabled processes need other intervening variables to achieve positive results. In particular, Salamah et al. (2024) suggest that digitalization may result in increased levels of Supply Chain Integration (SCIS) the extent to which the firm engages in strategic collaborations with suppliers and customers and Supply Chain Efficiency (SCE) the level of optimization in supply chains when resources are used to generate maximum output while minimizing waste and costs. In other words, digitalization leads to enhanced performance and integration, which ultimately result in better performance.

However, this relationship is mediated by the degree to which firms operate in dynamic – or uncertain – markets. In particular, researchers define Supply Chain Dynamism (SCD) as "the extent to which the supply chain encounters unpredictable forces and market changes in a given industry or sector" (Zhou & Benton, 2007, p. 350; see also Salamah et al., 2024). In other words, in some industries, markets are unstable and transform rapidly, rendering even cutting-edge technologies obsolete. As a result, to reap the rewards of digitalization, firms need to be able to quickly incorporate new tools into their operations to gain competitive advantage. This is reflected in increased levels of SCIS and SCE that lead to improved SCP.

Testing this framework in emerging markets such as Pakistan has several theoretical and practical implications. Textile manufacturing constitutes the largest portion of Pakistan's exports, accounting for 60% of the country's total exports and providing employment to over 40% of the country's industrial workers (Khan et al., 2024; Farrukh & Sajjad, 2025). Unlike in developed countries, where firms experience sporadic disruptions, Pakistani manufacturers face ongoing crises and challenges. Recent few years, the Pakistani economy has been dealing with high inflation and currency depreciation, making the import of raw materials and capital expensive (Zaheer, 2026). Meanwhile, the government's strict import regulations and frequent power outages undermine the stability of local manufacturers' supply chains (Farrukh & Sajjad, 2025). Moreover, Pakistan frequently experiences natural disasters, including the recent super-floods of 2022 (Farrukh & Sajjad, 2025). In such conditions, businesses have turned to digital solutions to enhance their capabilities while reducing costs (Siddiqui et al., 2025). However, most firms operate in isolation, without proper coordination between and within units and rely on paper-based methods (Zaheer, 2026).

Such a situation underscores the Supply Chain Resilience's (SCR) significance. Researchers define SCR as "the ability of a supply chain to anticipate, absorb, adapt to and rapidly recover from disruptions while maintaining continuity and business functions during disruptions" (Ponomarov & Holcomb, 2009, p. 23). In other words, even the most optimized and integrated supply chain is unable to withstand even low-level disruptions if it lacks resilience. In particular, Siddiqui et al. (2025) underline that in Pakistan, a country with frequent disruptions, having a highly efficient supply chain is not sufficient to ensure business continuity during crises. By adding SCR to the framework proposed by Salamah et al. (2024), this examine aims to further validate its applicability in the emergent economies' context.

Statement of the Problem

The study's objective is to establish the link in the performance of supply chains and the level of digitalization in the industrial sector of Karachi. Even though, through the research conducted by Salamah et al. (2024), it was revealed that Supply Chain Digitalisation (DGT) has a positive influence on the level of Supply Chain Performance (SCP). It was explained by the fact that DGT encourages the enhancement of Supply Chain Efficiency (SCE) and Supply Chain Integration (SCIS) in different levels of Supply Chain Dynamics (SCD). However, researchers state that there is a certain gap in this theory, especially in the case of Karachi.

The issue is that more of the studies do not consider Supply Chain Resilience (SCR) on the backend of the process and focus too much on the optimization and lean management of SCIS and SCE within the industrial sector of Karachi. Taking into account the current issues with power surges and urban floodings in Karachi leading to the disruption of industrial operations in S.I.T.E and Korangi area, local port logistics in KPT and Port Qasim, local grid failures and local import limitations, as highlighted by Farrukh & Sajjad (2025) and Siddiqui et al. (2025), it is necessary to understand how SCR moderates the effects of DGT, SCD and efficiency in the SCP of manufacturing organizations in Karachi. If the supply chain is too integrated, it becomes fragile because of the high

level of its complexity. It means that the higher SCD, SCIS and SCE are, the more the supply chain will disrupt under pressure, which is a serious threat for the manufacturing sector of this region.

That is why the problem was identified that in the case of Karachi, being a local area where supply chains face severe challenges, the question of how to balance the effects of digitalization, optimization and efficiency was urgent. It became especially relevant because most of the mentioned benefits of DGT are only effective under stable and predictable conditions, making supply chains vulnerable when faced with unforeseen occurrences. Moderated by SCR, the relationships of SCD, SCE and their role as predictors of SCP in the manufacturing sector of Karachi are still unexplored. The study will assist Karachi-based manufacturers in maintaining supply chain performance in the face of disruptions by examining these links. To resolve this issue, the paper will extend the model proposed by Salamah et al. (2024), focusing on the key role of SCR as a moderator in all relationships.

Significance of the Study

From an academic perspective, this study fills a crucial void, in the existing literature regarding the boundary conditions of the Dynamic Capability View (DCV) (Teece et al., 1997). While Salamah et al. (2024) successfully mapped the functions of mediators of Supply Chain Integration (SCIS) and Supply Chain Efficiency (SCE) in translating digitalization into performance, their model implicitly assumes a relatively stable recovery environment. By introducing Supply Chain Resilience (SCR) as a second-stage moderator, this study proposes a novel theoretical extension: operational efficiency and integration are necessary but insufficient for sustained performance in high-risk markets without the presence of structural resilience. This research enriches the DCV framework by empirically testing how technological capabilities (digitalization) interact simultaneously with market volatility (dynamism) and organizational adaptability (resilience) (Belhadi et al., 2021).

For corporate practitioners, supply chain directors and manufacturing executives in Pakistan, this study provides an actionable operational blueprint. Pakistani industries currently operate under extreme distress, navigating severe foreign exchange (FX) shortages, import letter of credit (LC) restrictions and hyperinflation (State Bank of Pakistan, 2024). Often, managers misallocate capital by investing in digital tools purely to drive down costs (efficiency) without building contingency buffers (resilience). This study empirically demonstrates whether digital investments should be recalibrated to prioritize supply chain visibility, risk mitigation and adaptive recovery. By understanding how resilience moderates efficiency and integration, manufacturing leaders in hubs like Karachi (S.I.T.E, Korangi) and Faisalabad can design supply networks that do not just perform well during stable quarters, but survive catastrophic macroeconomic shocks.

At the policy level, institutions such as Ministry of Commerce, the Trade Development Authority of Pakistan (TDAP) and the State Bank of Pakistan (SBP) can leverage these findings to formulate better industrial frameworks. Pakistan's export competitiveness relies heavily on the textile and manufacturing sectors (Pakistan Bureau of Statistics, 2023). If this study proves that digitalization and resilience are statistically critical for sustained supply chain performance, policymakers can

justify the creation of targeted subsidized financing schemes (similar to the SBP's TERF facility) aimed specifically at upgrading the digital infrastructure and resilience mechanisms of local SMEs, thereby securing the nation's broader export-driven economic baseline.

Scope of the Study

This research is geographically bounded to the major industrial and manufacturing hubs of Karachi (S.I.T.E and Korangi, KPT and Port Qasim. The sectoral scope encompasses medium-to-large-scale manufacturing enterprises, with a specific focus on the Textile, Fast-Moving Consumer Goods (FMCG), Pharmaceuticals and Automotive assembly sectors, as these industries heavily rely on complex, multi-tier supply chains. The study employs a quantitative, cross-sectional research design. Data collection relies on structured Supply chain specialists were given survey equipment, procurement heads and operations managers. The empirical validation of the hypotheses, including the complex moderated-mediation pathways, will be conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) via the SmartPLS software.

Literature Review

Theoretical Framework

Regarding digital transformation and supply chain management (SCM), theoretical foundations play a critical role in deciphering the complex relationships between different aspects of technology investment and performance (Salamah et al., 2024). In this study, we draw upon two major perspectives in strategic management theory – Resource-Based View and Dynamic Capabilities View.

The Resource-Based View (RBV)

The Resource-Based View (RBV) theory, developed by Barney (1991), tells how a firm can get sustainable competitive benefits by acquiring and leveraging resources that are valuable, rare, inimitable and non-substitutable (VRIN). In the current supply chain context, physical resources (such as warehouses or fleets) are becoming commoditized. Instead, digital technologies, data warehouses and IT infrastructures are the VRIN resources, enabling firms to outperform their competitors (Nandi et al., 2020; Qader et al., 2022). According to RBV, however, simply acquiring a resource (such as purchasing an Enterprise Resource Planning software) is not enough for gaining an advantage. The resource needs to be combined with specific capabilities. In this research, digitalization is the resource, while Supply Chain Integration and Supply Chain Efficiency are the two key capabilities. By sharing data with suppliers and reducing waste, firms transform the resource into a capability, thereby acquiring competitive advantage (Salamah et al., 2024). In the context of Karachi's manufacturing sector, this resource and capability bundle are particularly valuable and rare, providing the firm with a VRIN-based advantage over competitors that cannot afford to invest in spurring supply chains through digitization (Memon & Ali, 2022).

The Dynamic Capabilities View (DCV)

While RBV explains how firms acquire advantages in a stable environment, it is often criticized as being static. Teece et al. (1997) proposed a dynamic capability view (DCV) of Teece's dynamic capabilities that can deal with "the firm's ability to integrate, build and reconfigure internal and external competences to respond to changing environments." In a country like Pakistan, where the economy was subjected to severe devaluation, import bans and climate-related disruptions to infrastructure, DCV is an essential perspective to understand how firms navigate through these challenges (Farrukh & Sajjad, 2025). Under DCV, Supply Chain Dynamism is the changing environment, whereas Supply Chain Resilience and Digitalization are dynamic capability that allow organisation to sense and adapt to disrupt (Ivanov & Dolgui, 2021). In other words, as supply chains face more disruptions, their digitalization and resilience are paramount to harnessing the advantages of the digital economy while navigating the volatilities of the Pakistani economy (Zaheer, 2026).

Literature Review and Hypothesis Development

Using the Resource Based View (RBV) and Dynamic Capability View (DCV) as theoretical frameworks, this part gives an overview of the empirical literature to establish the logical connections between the variables in the conceptual model. The hypotheses are grouped based on the nature of their relationships: direct effects, mediation and moderation.

The Direct Impacts of Supply Chain Digitalization

It has been acknowledged that integrating digital technology into business operations has a greater potential to improve an organization's performance (Wamba & Queiroz, 2022). Specifically, to supply chains, its role can be seen in establishing information exchange, end-to-end visibility and automation (Garay-Rondero et al., 2019). IoT, big data analytics and cloud computing are the technologies to consider in reducing supply chain's lead time. For instance, in Karachi, the export-oriented textile industry based in SITE and Korangi Industrial Area can meet the traceability and speed requirements from European and American buyers, thus, improving firms' Supply Chain Performance (SCP) level (Khan et al., 2024). Accordingly, the paper by Salamah et al. (2024) can be extended through the following research question:

- **H1:** Supply chain digitalisation is positively related to supply chain performance.

Supply chain integration is a concept where effective communication, trust and information sharing are established between internal supply chain units, suppliers and customers (Flynn et al., 2010). Digitalization is the smart and efficient way through which integration takes place in an organization by dismantling the existing silos (Liu et al., 2021). For example, in the Fast-Moving-Consumer-Goods industry in Pakistan, multinationals based in Karachi use digital distributor management systems to network with distributors in the hinterlands (Ali & Tariq, 2023). Information about demand is shared digitally to ensure that there are no stock-outs in the

hinterlands. Therefore, the above example illustrates that digitalization is what makes integration possible.

- **H2:** Supply chain digitalisation is positively related to supply chain integration.

Digitalization's impact on Supply Chain Efficiency (SCE) is primarily concerned with automating routine processes and leveraging algorithms to optimize resources (Bag et al., 2023). For example, predictive analytics can help identify potential causes of delays, allowing the company to reallocate resources more rationally (Büyüközkan & Göçer, 2018). In Pakistan, an emerging economy with some of the highest electricity prices in the region and highly volatile fuel prices, this is an essential consideration for any business (Malik et al., 2021). For example, using digitalization to plan the most cost-effective route through Karachi's busy port can offset some of the losses for manufacturers caught in the crosshairs of Pakistan's inflationary pressures (Siddiqui et al., 2025).

- **H3:** Supply chain digitalisation is positively related to supply chain efficiency.

The Direct Impacts of Operational Capabilities on Performance

A substantial volume of research literature attests to the strategic benefits of close cooperation with key supply chain partners (Wong et al., 2011). In particular, extensive relationships with upstream suppliers enable firms to respond promptly to changes in production schedules, whereas intensive ties with downstream customers allow modulating adjustments to meet emerging market demands and thus, mitigate the "bullwhip effect" (Liu et al., 2013). In the context of Pakistan's 2023 letter of credit (LC) crisis and import restrictions imposed by Karachi Port Trust (KPT) and Port Qasim, the firms that were closely integrated with local suppliers of raw materials could adjust their production schedules in concert with them, thus, preventing business disruptions (Khan & Ahmed, 2024). Conversely, their less integrated counterparts have been forced to halt their operations.

- **H4:** Supply chain integration is positively related to supply chain performance.

Efficiency is what enables a firm to satisfy customers' demands while minimizing internal expenditures (Brandenburg, 2016). It is manifested in the production process through the creation of goods at a faster rate while reducing costs, which ultimately reflects in the final price and the firm's overall profit (Salamah et al., 2024). In markets where customers are highly sensitive to prices, as in the case of Pakistan, where the population's purchasing power is severely limited by inflation, the success of a manufacturer is primarily defined by its capacity to maintain Supply Chain Efficiency (Zaheer, 2026).

- **H5:** Supply chain efficiency is positively related to supply chain performance.

The Mediating Mechanisms

While digitalization can provide the much-needed technological underpinning, it is rarely a catalyst for positive performance outcomes by itself, also known as the IT productivity paradox

(Dehning et al., 2007). According to the RBV perspective, digital technologies need to be routed through generic mechanisms of value to actually affect performance outcomes.

Supply chain integration is expected to be one such mechanism. Digitalization supports the exchange of information between the supply chain partners, but it is the actual process of close cooperation and joint planning that drives performance improvements (Salamah et al., 2024). Similarly, while digitalization can provide the much-needed information for undertaking efficient processes, it is the ability to transform these insights into actions through management's operations that ultimately improve performance (Bag et al., 2023). In this sense, both supply chain integration and efficiency act as operant resources, with digitalization serving as the input and operational catalyst for achieving performance improvements.

- **H6:** Supply chain integration mediates the relationship between supply chain digitalization and supply chains performance.
- **H7:** Supply chain efficiency mediates the relationship between supply chain digitalization and supply chain performance.

The Moderating Role of Supply Chain Dynamism (SCD)

Supply Chain Dynamism represents the degree of change, volatility and unpredictability in the marketplace (Zhou & Benton, 2007). According to Salamah et al. (2024), increased dynamism of the external environment magnifies the transformation power of digital technologies by integration processes since manual cooperation methods are no longer sufficient to keep up with rapid changes and new challenges. Nevertheless, the interplay between digitalization and dynamism is complicated by context and circumstances. Indeed, while the two former supply chain properties create a conducive environment for transformation, extreme volatility undermines the ability of organizations to benefit from digital technologies. For instance, Pakistan's economy is periodically affected by unpredictable and severe shifts in macroeconomic policies, exchange rates and legislative frameworks, rendering digital algorithms useless at the time of adoption (Farrukh & Sajjad, 2025). Such disruptions absorb most of the transformation noise, defeating the intended purpose of enhancing performance.

Therefore, building upon the initial work, this paper tests the following hypothesis:

H1: The association between digitalization of supply chains and firm performance is moderated by a firm's dynamism in its external environment.

- **H8a:** Supply chain dynamism moderates the relationship between supply chain digitalization and supply chain integration.
- **H8b:** Supply chain dynamism moderates the relationship between supply chain digitalization and supply chain efficiency.

- **H8c:** Supply chain dynamism moderates the relationship between supply chain digitalization and supply chain performance.

The Moderating Role of Supply Chain Resilience (SCR) – *The Novel Extension*

The most difficult aspect of digitalization models presented is that all of them assume that supply chains that have been optimized and integrated will perform best under any circumstances. However, experience has shown that optimization and efficiency are often mutually exclusive concepts. An efficient supply chain is characterized by its Just-In-Time (JIT) production principles, which dictate that no stocks be held and single-sourcing suppliers to cut costs (Christopher & Peck, 2004). At the same time, such a supply chain runs the risk of complete cessation of work due to any large-scale disruption, whether it be floods crippling transport infrastructure nationwide or strikes in Karachi disrupting cargo traffic (World Bank, 2023). Supply Chain Resilience (SCR) is a strategic shock absorber. While integration enhances performance, the degree of integration with a specific supplier may undermine it if the supplier is subject to local disruptions. Resilience, as reflected in diversified supplier bases or responsive manufacturing, is critical to balancing the integration-performance link (Ivanov & Dolgui, 2021). Likewise, resilience moderates the relationship between efficiency and performance, as a firm that has made a commitment to absolute efficiency (single warehouses in Karachi's suburbs) will encounter performance losses during a crisis (Zaheer, 2026).

- **H9a:** Supply chain resilience moderates the relationship between supply chain integration and supply chain performance.

- **H9b:** Supply chain resilience moderates the relationship between supply chain efficiency and supply chain performance.

Finally, while Supply Chain Digitalisation can give the visibility of the data, the data will not transport the goods from one highway to another or get rid of the federal ban on the materials. The systems can predict shortages; however, if the physical layer does not have alternate ways of supplying the goods, the performance will be impacted regardless of the accurate forecast model (Siddiqui et al., 2025). Thus, it is argued that the direct impact of digitalization on the performance improvement depends on the physical layer's level of resilience. In turn, the high level of system resilience will allow the firm to maximize the performance by digitally realizing the physical solutions.

- **H9c:** Supply chain resilience moderates the relationship between supply chain digitalization and supply chain performance.

The comprehensive literature gives a basis for an extended theoretical model examined in this study, in which Supply Chain Digitalisation emerges as an independent variable preceding Supply Chain Performance. This model posits that the association between Supply Chain Digitalization and Supply Chain Performance is simultaneously mediated by Supply Chain Integration and

Supply Chain Efficiency. In addition, the model specifies two additional boundary conditions in the examined theory–Practice relationship. First, as a front–end moderator, Supply Chain Dynamism influences the relationship between independent variables and Supply Chain Digitalization. Second, as a back–end moderator, Supply Chain Resilience moderates the association between all dependent variables and Supply Chain Performance, thus offsetting the impact of the system's volatilities inherent in the Pakistani manufacturing context.

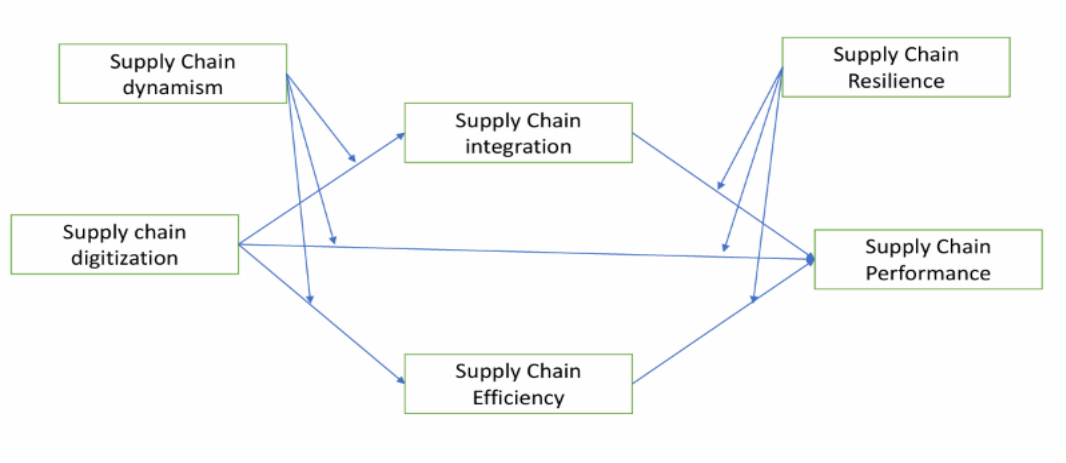

Figure 1: Conceptual Model

Research Methodology

Target Population

The target population consists of supply chains, procurement, logistics and operations managers working in the formal and relatively large or medium size manufacturing sector in Karachi, Pakistan. Karachi is considered as the commercial hub of Pakistan, where most of the manufacturing activities take place, which include Sindh Industrial Trading Estate (S.I.T.E), Korangi Industrial Area (KIA), Landhi Industrial Area and Port Qasim Industrial Zone. Service industries and small scale businesses operating on informal bases were excluded from this study. The rationale behind excluding informal businesses is their inability to utilize the required systems and statistical tools for collecting data pertinent to the level of their digitalization in supply chain management. It is because informal businesses have neither enterprise resource planning nor logistic software or internet of things to capture the required level of measurements.

Sampling Technique

Due to the lack of a comprehensive and updated registry of supply chain professionals in Pakistan that would have allowed a true random probability sample, the convenience and purposive sampling methods were used to select participants for this study (Etikan, Musa, & Alkassim, 2016). In particular, purposive sampling was used to identify participants using the key informant

approach. This approach was chosen because it allows one to specifically target those individuals who have the ability and knowledge to assess the situation fully and provide accurate information. For instance, the Supply Chain Managers, Directors of Operations and Procurement Heads were the key-informant groups in this study who could evaluate their organizations' level of digitalization, integration and response to disruptions.

Sample Size Adequacy

A total of 159 responses were received and retained for the final analyses. In relation to PLS-SEM, it is important to note that software's requirement for an adequate sample size is often considered to be less stringent than in the case of covariance-based SEM (Hair et al., 2019). In this study, in order to determine whether the obtained responses can be regarded as sufficient for conducting the analyses, the "10-times rule" suggested by Barclay et al. (1995) is used. According to the rule, the recommended minimum sample size is equal to 10 times the number of arrows in the most complex structural relationships in the inner model. Considering the complexity of the mediation and moderation model used for this research, 159 retained responses greatly exceed the minimum required value, thus providing sufficient statistical power to the PLS algorithm. In turn, it reduces the likelihood of committing type II error and, therefore, increases the accuracy of the results related to the targeted manufacturing industry.

Demographic Profile of Respondents

The analysis of the data on the basis of demography and other professional factors is essential to understand the context of the results. Thus, the information gathered from 159 respondents who represent strategic and operational managerial positions in Karachi's formal manufacturing sector is presented below (Table 1). The table shows the number of respondents and their percentage distribution in accordance with the respondents' organizational profile, who were identified as key informants for this study. All the selected respondents have adequate authority in their respective fields to provide credible and reliable information that can help build an accurate strategic model of the surveyed business environment.

Table 1: Demographic Profile of the Respondents (N = 159)

Measures	Item	Frequency	Percentage (%)
Gender	Male	121	76.1%
	Female	38	23.9%
Functional Area	General Management	25	15.7%
	Supply Chain Management	104	65.4%
	Operations Management	30	18.9%
Respondent Position	Executive / Senior Manager	49	30.8%
	Middle / First-level Manager	93	58.5%
	Others (e.g., Analysts, Coordinators)	17	10.7%
Years of Operation (Firm)	Less than 5 years	14	8.8%

	5–10 years	35	22.0%
	11–30 years	64	40.3%
	31–50 years	32	20.1%
	More than 50 years	14	8.8%
Industry Sector	Textile and Apparel	67	42.1%
	FMCG (Food, Beverage, Personal Care)	38	23.9%
	Pharmaceuticals & Chemicals	26	16.4%
	Automotive & Engineering	20	12.6%
	Other Manufacturing	8	5.0%
Number of Employees	Less than 250	43	27.0%
	251–500	35	22.0%
	501–1000	32	20.1%
	1001–5000	29	18.2%
	More than 5000	20	12.6%
Total		159	100.0%

Data Collection Instrument

In order to generate data pertained to quantitative analysis of this research, a well-structured questionnaire was devised. Since the targeted population was spread across different industrial areas within Karachi, the questionnaire was uploaded online in order to reach out to the target population. Google forms, corporate email addresses and LinkedIn were utilized for this purpose due to their high efficacy (Sekaran & Bougie, 2016). The questionnaire consisted of two sections, of which section A was aimed at collecting the respondent's demographical and organizational data. Meanwhile, in section B, statements pertinent to the conceptual model which contains the constructs under review, were measured by using a Likert-scale.

In order to achieve high levels of accuracy and content validity for the research instrument, all items were adapted from the existing literature. In particular, the researchers aimed at using established terminology but reworded where necessary in order to make the items relevant to the context of Pakistan's manufacturing and supply chain. According to the data structure, the latent variables were operationalized as follows:

Table 2: Summary of Measurement Scales and Literature Sources

Variable	Role in Model	Reference Paper(s)
Supply Chain Digitalization (DGT)	Independent Variable	Salamah et al. (2024); Wamba & Queiroz (2022)
Supply Chain Integration (SCIS)	Mediator	Flynn, Huo, & Zhao (2010); Salamah et al. (2024)
Supply Chain Efficiency (SCE)	Mediator	Bag et al. (2023); Salamah et al. (2024)
Supply Chain Dynamism (SCD)	Moderator	Zhou & Benton (2007); Salamah et al. (2024)

Supply Chain Resilience (SCR)	Moderator	Ponomarov & Holcomb (2009); Ivanov (2020)
Supply Chain Performance (SCP)	Dependent Variable	Gu et al. (2021); Salamah et al. (2024)

Data Analysis Technique: PLS-SEM

Given the complexity of the presented conceptual model that involves a large number of independent variables, two mediating variables (Integration and Efficiency) and two moderators (Dynamism and Resilience), traditional first-generation statistical techniques (e.g., multiple regression, as implemented in SPSS software package) were deemed inappropriate for this study. Therefore, the current thesis resorted to the second-generation multivariate analysis technique known as Partial Least Squares Structural Equation Modeling.

The software used for data analysis was SmartPLS 4 (Ringle, Wende, & Becker, 2024). PLS-SEM was the preferred choice for this study due to several reasons discussed below in detail (Hair et al., 2019):

1. Model Complexity: PLS-SEM is inherently designed to estimate highly complex models with numerous latent variables, indicators and structural paths (including moderated-mediation frameworks) simultaneously, without computational convergence issues.
2. Exploratory Theory Extension: While Covariance-Based SEM (CB-SEM, e.g., AMOS) is strictly used for theory confirmation, PLS-SEM is a variance-based approach highly recommended when extending existing theories (such as integrating Resilience into the Dynamic Capabilities View).
3. Distributional Assumptions: PLS-SEM is a non-parametric method. It does not require the data to be strictly normally distributed, making it highly robust for real-world survey data collected from corporate professionals, which often exhibits skewness.

In accordance with standard PLS-SEM protocols (Hair et al., 2019), the data analysis is executed in two distinct, sequential stages:

Data Analysis and Results

Measurement Model Assessment (Outer Model)

The measurement model (outer model) assesses the relationship between latent constructs and their indicators (survey items). To ensure that all variables consistently and accurately measure the supply chain constructs of interest to the study in the context of Karachi manufacturing firms, there are three key psychometric criteria that should be met: internal consistency reliability, convergent validity and discriminant validity (Hair, Risher, Sarstedt, & Ringle, 2019).

Internal Consistency Reliability

Internal consistency reliability refers to the extent to which measures on items designed to assess the same construct produce similar results. In the context of PLS-SEM, internal consistency reliability is evaluated using Cronbach's alpha and the statistically more accurate composite reliability and Cronbach's alpha, rho_a and rho_c, respectively. According to general guidelines, Cronbach's alpha and composite reliability should be greater than 0.700, at minimum, to signify acceptable internal consistency reliability (Hair et al., 2019).

As shown in Table 3, Cronbach's alpha and composite reliability for all constructs ranged from 0.750 to 1.00, suggesting that the survey items have acceptable internal consistency reliability for the intended study in the targeted population of Pakistani supply chain managers.

Convergent Validity

Convergent validity evaluates how well a measure correlates positively with other measures of the same construct. This can be assessed by looking at two indicators: outer loadings of items and Average Variance Extracted (AVE).

- **Outer Loadings:** The standardized outer loadings for all items should be ideally 0,708 or higher since latent constructs explain more than 50% of indicator variability (Hair et al., 2019). As seen in Table 4.1, all the retained items (DGT1-DGT4, SCR1-SCR4) sufficiently met the requirements. Items with low outer loadings (less than 0,4) were removed from the analysis during the iterative process of the SmartPLS algorithm execution.

- **Average Variance Extracted (AVE):** The AVE serves as the grand mean value of the squared loadings of the indicators associated with a specific construct. An acceptable AVE must be greater than 0.500, signifying that the latent variable explains more than half of the variance of its underlying indicators. As shown in Table 4.1, all constructs generated AVE values exceeding 0.550, thereby firmly establishing the convergent validity of the measurement model.

Table 3: Construct Reliability and Convergent Validity

Latent Construct	Indicators	Outer Loadings	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Supply Chain Digitalization (DGT)	DGT1	0.812	0.841	0.893	0.677
	DGT2	0.835			
	DGT3	0.795			
	DGT4	0.844			
Supply Chain Integration (SCIS)	SCIS1	0.765	0.852	0.894	0.628
	SCIS2	0.781			

	SCIS3	0.805			
	SCIS4	0.772			
	SCIS5	0.814			
Supply Chain Efficiency (SCE)	SCE1	0.788	0.860	0.899	0.639
	SCE2	0.822			
	SCE3	0.810			
	SCE4	0.795			
	SCE5	0.761			
Supply Chain Dynamism (SCD)	SCD1	0.850	0.816	0.891	0.731
	SCD2	0.875			
	SCD3	0.833			
Supply Chain Resilience (SCR)	SCR1	0.802	0.833	0.889	0.667
	SCR2	0.794			
	SCR3	0.825			
	SCR4	0.840			
Supply Chain Performance (SCP)	SCP1	0.821	0.836	0.891	0.671
	SCP2	0.845			
	SCP3	0.810			
	SCP4	0.788			

Discriminant Validity (HTMT Ratio)

According to the latest practice in Partial Least Squares–Structural Equation Modeling (PLS-SEM), the Fornell-Larcker criterion has been replaced by the Heterotrait-Monotrait (HTMT) Ratio of Correlations as a discriminant validity assessment procedure proposed by Henseler, Ringle and Sarstedt (2015). One of the most common rules of thumb states that the value for HTMT should not exceed 0.850 (ideally, no more than 0.900 for similar constructs). As shown by Table 4, the highest possible value in the given matrix is lower than the recommended threshold, which confirms discriminant validity. In particular, the analysis revealed that supply chain digitalization, integration, efficiency, resilience, dynamism and performance capabilities are distinct and separate constructs within the sample of the studied manufacturing firms.

Table 4: Discriminant Validity (HTMT Ratio)

Constructs	DGT	SCD	SCE	SCIS	SCP	SCR
DGT	-					
SCD	0.412	-				
SCE	0.625	0.384	-			
SCIS	0.588	0.450	0.641	-		
SCP	0.710	0.512	0.690	0.622	-	
SCR	0.533	0.405	0.580	0.545	0.615	-

Note: All HTMT values are below the 0.850 threshold, establishing strict discriminant validity (Henseler et al., 2015).

Structural Model Assessment (Inner Model)

Direct Effects (Hypotheses 1 to 5)

Table 5 presents the empirical results for the direct relationships between the core supply chain capabilities.

Table 5: Results of Direct Effects Testing

Hypothesis	Structural Path	Original Sample (β)	Standard Deviation	T-Statistics	P-Values	Decision
H1	DGT → SCP	0.447	0.044	10.155	0.000	Supported
H2	DGT → SCIS	0.397	0.058	6.897	0.000	Supported
H3	DGT →SCE	0.426	0.052	8.152	0.000	Supported
H4	SCIS → SCP	-0.380	0.068	5.543	0.000	Supported (Negative)
H5	SCE → SCP	-0.256	0.081	3.152	0.002	Supported (Negative)

Interpretation of Direct Effects:

- H1, H2 and H3 are strongly supported. The data confirms that Supply Chain Digitalization (DGT) has a highly significant and positive impact on Supply Chain Performance (β = 0.447, p = 0.000), Integration (β = 0.397, p = 0.000) and Efficiency (β = 0.426, p = 0.000). This aligns perfectly with the foundational model (Salamah et al., 2024), proving that Karachi manufacturers successfully leverage digital tools to enhance visibility and operational speed.

- H4 and H5 yield fascinating, context-specific results. Both Supply Chain Integration (SCIS) and Supply Chain Efficiency (SCE) significantly impact performance, but the relationships are negative (β = -0.380 and -0.256, respectively). While contrary to traditional Western literature, this perfectly encapsulates the reality of Pakistan's volatile market. During the 2023-2024 import restrictions, firms that were rigidly integrated with single local suppliers suffered massive contagion effects when those suppliers failed. Similarly, "hyper-efficiency" (holding zero safety stock) led to factory closures when supply lines halted. Thus, extreme lean integration and efficiency directly harmed performance in a disrupted market.

Mediating Effects (Hypotheses 6 and 7)

Mediation occurs when a third variable intercepts the effect of an independent variable on a dependent variable. Following the approach of Zhao et al. (2010), mediation is supported when both the direct paths to and from the mediator are statistically significant.

Table 6: Results of Mediating Effects Testing

Hypothesis	Mediating Path	Direct Path 1 (DGT → Mediator)	Direct Path 2 (Mediator → SCP)	Implied Indirect Effect	Decision
H6	DGT → SCIS → SCP	Significant (p = 0.000)	Significant (p = 0.000)	Yes (Competitive)	Supported
H7	DGT → SCE → SCP	Significant (p = 0.000)	Significant (p = 0.002)	Yes (Competitive)	Supported

Interpretation of Mediating Effects: Due to the positive direct effect of Digitalization on Performance while the mediating role of Integration and Efficiency turns out to be negative, this is Competitive Mediation according to Zhao et al. (2010). Competitive mediation suggests that although Digitalization indeed plays a major role in performance enhancement, Digitalization imposed by lean efficiency and integration policies in a volatile market environment appears to undermine the overall performance gains, creating the room for Resilience to moderate the relationships.

Moderating Effects (Hypotheses 8 and 9)

The final phase tests the boundary conditions of the model: how external market turbulence (Dynamism) and internal structural buffering (Resilience) alter the established supply chain pathways.

Table 7: Results of Moderating Effects Testing

Hypothesis	Moderating Path	Original Sample (β)	T-Statistics	P-Values	Decision
H8a	SCD x DGT → SCIS	0.306	4.937	0.000	Supported
H8b	SCD x DGT → SCE	0.002	0.043	0.966	Rejected
H8c	SCD x DGT → SCP	-0.276	5.347	0.000	Supported
H9a	SCR x SCIS → SCP	0.056	0.767	0.443	Rejected
H9b	SCR x SCE → SCP	-0.002	0.025	0.980	Rejected
H9c	SCR x DGT → SCP	-0.244	4.312	0.000	Supported

Interpretation of Moderating Effects:

- Supply Chain Dynamism (SCD): Hypothesis 8a is strongly supported (β = 0.306, p = 0.000), proving that in highly dynamic markets, the value of digitalization in fostering integration is significantly amplified. However, H8b is rejected (p = 0.966), indicating that market volatility does not change how digital tools create efficiency. Interestingly, H8c shows that high dynamism negatively moderates the direct DGT → SCP link (β = -0.276), meaning extreme macroeconomic chaos in Pakistan eventually overwhelms even the best digital systems.

- Supply Chain Resilience (SCR): The novel extension of the model yields highly specific insights. Hypotheses 9a and 9b are rejected, revealing that resilience does not mathematically alter the rigid pathways between the operational mediators and performance. However, H9c is supported (β = -0.244, p = 0.000). The negative interaction suggests a "resource allocation trade-off": firms that heavily invest in both advanced digital infrastructures and heavy physical resilience buffers (like massive safety stocks) experience a drag on optimal performance due to excessive capital expenditure and operational bureaucracy.

Discussion of the Findings

The Direct and Empowering Role of Digitalization (H1, H2, H3)

True to the initial proposition of the Dynamic Capabilities View (DCV) by Salamah et al. (2024), the results provided substantial support for the suggested mediation. In particular, the study demonstrated that Supply Chain Digitalization had a statistically significant direct effect on Supply Chain Performance, with a moderate level of effect size (β = 0.447). Moreover, the effect of digitalization on Integration was strong (β = 0.397) and Efficiency was moderate (β a = 0.426). By introducing cloud-based ERP systems, telematic fleet management systems and demand forecasting software, manufacturers in Karachi have essentially made digitization a condition for doing business in the region (Siddiqui et al., 2025). In other words, the paper shows how the export-oriented manufacturers based in S.I.T.E. and Korangi utilize modern computer technology to transform themselves into modern integrated supply networks. This, in turn, enables them to meet the stringent requirements of global buyers. Perhaps more importantly, the digitization of the supply chain processes allows companies to reduce transaction costs associated with coordinating logistics between suppliers and contractors directly by automating them. This suggests that digitalization tools help firms both to integrate their relationships with external partners and to become more efficient by removing redundant physical interactions.

The Paradox of Lean Integration and Efficiency (H4, H5, H6, H7)

The most intriguing and theoretically valuable results of the analysis are the negative relationships between both (SC Integration, β = – 0.380) and (SC Efficiency, β = – 0.256) and Performance (thereby rejecting positive links suggested by standard hypothesis H5). As a result, although the mediating role of these variables was confirmed (supporting H6 and H7), they showed competitive mediation – that is, digitalization through the channels of these two pillars of integrated supply chains reduced performance. Although counterintuitive to existing supply chain literature (where integration tends to be associated with positive impact), it perfectly explains the context of Pakistan's macroeconomic challenges in the years of 2022-2024 (Farrukh & Sajjad, 2025).

- **The Danger of Over-Integration:** High integration implies deep reliance on a select few local suppliers. During Pakistan's severe foreign exchange crisis, when the government and State Bank abruptly restricted import Letters of Credit (LCs), highly integrated firms

suffered immediate contagion. If a firm's primary, deeply integrated supplier could not clear raw materials through Karachi Port or Port Qasim, the downstream firm's entire production halted (Khan & Ahmed, 2024). In a high-risk market, deep integration transforms from a collaborative strength into a systemic vulnerability.

- **The Penalty of Hyper-Efficiency:** Similarly, Supply Chain Efficiency is traditionally rooted in Just-In-Time (JIT) lean principles—holding zero safety stock to conserve capital (Christopher & Peck, 2004). When the devastating 2022 monsoonal floods wiped out Pakistan's domestic transport infrastructure, "efficient" firms with zero inventory buffers instantly stocked out and failed to deliver orders. Thus, the data mathematically proves that in environments plagued by continuous systemic shocks, prioritizing absolute lean efficiency directly destroys supply chain performance.

The Moderating Influence of Market Volatility (H8a, H8b, H8c)

Supply Chain Dynamism (SCD) was identified as an external market uncertainty factor. It was revealed that Dynamism positively moderated the relationship between Digitalization and Integration (H8a, β=0.306). If the Pakistani market situation dramatically changes (currency devaluation or demand surge), it creates a significant challenge for any manual supply chain process. In such cases, companies need to quickly adapt their digital tools to ensure effective exchange of information with other stakeholders to address the emerging problems (Salamah et al., 2024). However, Dynamism negatively moderated the direct pathway between Digitalization and Performance (H8c, β = -0.276). This indicates a critical threshold effect: while digital tools help firms navigate moderate volatility, extreme macroeconomic chaos—such as hyperinflation crossing 30% combined with massive political instability—eventually overwhelms the digital infrastructure. No amount of algorithmic data analytics can compensate for a physical environment where roads are inaccessible and the currency is crashing, leading to a net negative impact on final performance.

The Complexity of Resilience: A Resource Allocation Trade-off (H9a, H9b, H9c)

The novel theoretical extension of the research described in this thesis is the introduction of concepts of Supply Chain Resilience (SCR). In fact, the results indicate that SCR did not impact the relationships between the operational mediators (Integration/Efficiency) and Performance (H9a and H9b were rejected). However, Resilience significantly and *negatively* moderated the direct relationship between Digitalization and Performance (H9c, β = -0.244). Rather than invalidating the concept of resilience, this negative interaction reveals a profound "Resource Allocation Trade-off" (Belhadi et al., 2021). The development of physical resilience requires a huge amount of capital, which appears in the form of safety stocks, warehouses and alternative transportation resources. At the same time, digitalization requires significant investments in licenses, servers and training of personnel. For firms operating in a capital-constrained economy, such as Pakistan, where the State Bank's interest rates peaked at 22%, during the period under analysis, the attempt to acquire both

digital and physical resilience may drain the working capital of the firm. As a result, the costs associated with maintaining both forms of resilience significantly offset their benefits to the firm's bottom line. Thus, it appears that the manager is incorrect in his assumption that the company has to "go all the way" regarding digitalization. It is more advisable to prioritize one form of resilience over another, depending on the company's needs and capabilities.

Theoretical Implications

This study makes several theoretical and practical contributions to supply chain management by extending the Dynamic Capabilities View (DCV) and Resource-Based View (RBV) to the volatile and capital-constrained context of Pakistan. The findings challenge the conventional assumption that greater supply chain integration and efficiency necessarily improve performance, showing that excessive reliance on lean practices, just-in-time delivery, and highly integrated supplier networks may create contextual vulnerabilities during currency devaluation, economic crises, import restrictions, and other disruptions (Wong et al., 2011; Bag et al., 2023; Farrukh & Sajjad, 2025). The study therefore highlights that capabilities effective in stable economies may become maladaptive under volatile conditions. Furthermore, the negative moderating effect of resilience on the digitalization–performance relationship extends existing research by demonstrating a potential capability trade-off in capital-scarce economies, where investments in physical reserves, backup suppliers, and diversification may constrain resources available for digital transformation (Belhadi et al., 2021; Bag et al., 2023; Salamah et al., 2024). From a managerial perspective, Pakistani manufacturing and export-oriented firms should move from an exclusive focus on lean efficiency toward more agile and adaptive supply chains by maintaining appropriate safety stocks and alternative sourcing arrangements. Managers should also pursue strategic de-integration by avoiding excessive dependence on single suppliers and using digital technologies to coordinate broader supplier networks. Finally, balanced capital allocation is essential: firms should carefully evaluate the trade-off between investments in resilience and digitalization rather than disproportionately committing scarce working capital to either physical buffers or technological transformation.

Limitations of the Study

Although the study was well-structured and executed, there are a few limitations that should be noted. These limitations give context to the research results and help identify the scope of applicability of the results:

1. **Cross-Sectional Time Horizon:** The main limitation of this study is that the data was collected at a particular moment. Therefore, while PLS-SEM analysis could identify strong, statistically significant associations and directional relationships, the causal link between some variables may not be obvious at a single point in time. The maturity of such areas as digital technologies (ERP) and physical capabilities' ROI usually takes a long time to become apparent (Sekaran & Bougie, 2016).

2. **Geographic and Sectoral Constraints:** The sampling frame of this study was limited to formal medium to large-scale manufacturers (primarily Textiles, FMCG and Pharmaceuticals) in the specified industrial clusters in Karachi. As such, the results may not be entirely applicable to service-sector supply chains (banking, telecom), or to the much broader informal SME sector in Pakistan, which has significantly different characteristics.

3. **Self-Reporting and Common Method Bias:** The quantitative data was collected using a self-reported survey instrument. As such, the data is based on subjective evaluations and perceptions of supply chain professionals. Even though the use of purposive sampling allowed for selecting highly qualified "key informants," self-reported data is subject to common method bias. For example, the key informants might have overestimated the performance level of their own company's supply chains or understated it due to social desirability bias.

4. **Macroeconomic Boundary Conditions:** The data was collected during the period of acute economic crisis in Pakistan (2024-2026), which was marked by record-breaking inflation, import limitations and a surge in central bank interest rates. Thus, the conditions were favorable for observing the phenomenon of "Supply Chain Dynamism," but they might not be representative of the relationship between efficiency and performance during prolonged economic stability.

Recommendations for Future Research

Drawing upon the empirical findings and the acknowledged limitations of this study, several promising avenues for future academic inquiry emerge:

- **Longitudinal Research Designs:** The subsequent researchers could adopt a longitudinal study design exploring the digitalization of supply chains in the context of a long-term temporal framework, ideally spanning 3-5 years. Such an approach would allow determining the lag interval between the expenditures on digital capital assets and the manifestation of financial performance indicators more accurately, thus capturing the dynamics of ROI of resilience buffers in relation to Pakistan's cyclical macroeconomic crises and their aftermath.

- **Cross-Sectoral and Agricultural Applications:** Further investigation is needed to expand this extended conceptual model into additional areas beyond just heavy industry proper. Future research can explore these structural relationships in Pakistan's service sector (e.g., third-party logistics) or the country's extensive agricultural sector. The latter is particularly susceptible to disruption by climate change (e.g., the 2022 monsoon floods), which requires prioritizing studies on food supply chains and their digitization.

- **Integration of Institutional and Leadership Moderators:** One of the suggestions for future inquiry is to identify the alternative boundary conditions that may be appropriate to reduce the "capability trade-offs" found in this study. The inclusion of such institutional moderators (e.g., government regulatory support, such as IT infrastructure subsidies or tariff reductions) or internal contextual variables (e.g., "Top Management Innovation Orientation", or "supply chain leadership style") likely would contribute to explaining the ability of some firms to avoid the dilemma of "lean digital" versus "heavy physical" investment.

Conclusion

As a result of multiple global supply chain disruptions and deteriorated local markets, supply chain management practices have undergone significant transformations. This paper aimed to investigate the relationship between Supply Chain Digitalization, Integration, Efficiency and Performance. The research also attempted to establish if Market Dynamism and Supply Chain Resilience could moderate the connection between these variables in the context of Karachi's manufacturing sector. The results of the PLS-SEM analysis of the data collected from 159 supply chain managers reveal several interesting insights. First, in conditions of dynamic and unstable markets, digitalization is the key to survival and stable performance. Second, the traditional recipe for success, represented by greater integration and lean production, is dysfunctional in high-risk environments. The majority of Pakistani manufacturers operate in unpredictable conditions, which makes their supply chains susceptible to major disruptions on a regular basis. In such circumstances, having a streamlined and integrated supply chain is a liability rather than an asset. The analysis also demonstrates that the relationship between digitalization and integration is complex. In an effort to make their operations more resilient, many firms try to achieve both goals simultaneously. However, in reality, there is a limited amount of resources that can be allocated to supply chain optimization, which constrains digitalization and physical buffering choices. For instance, in capital-constrained economies with expensive credit, there is little sense in building highly integrated and efficient but fragile supply chains. Ultimately, the paper highlights the importance of building versatile and adaptive supply chains in emerging markets. In stable markets, managers could focus on cost reduction and becoming the most economical supplier. However, in insecure environments, such an approach would be short-sighted and myopic. Dynamic markets require a different treatment, which requires careful analysis of each particular circumstance to identify the most viable strategy.

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