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How Absorptive Capacity Mediates Supply Chain Effectiveness: A Quality Integration Approach to Boosting Operational Performance

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. **Operations Management Research**

How Absorptive Capacity Mediates Supply Chain Effectiveness: A Quality Integration Approach to Boosting Operational Performance

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Abstract

The importance of leveraging external knowledge to enhance quality management across the supply chain (SC) is well established in improving operational performance. However, empirical evidence on how this process unfolds remains limited. This study investigates the mediating impact of absorptive capacity (AC) on the relationship between supply chain quality integration (SCQI) and operational performance. We propose a five-step sequential mediation model, where customer and supplier quality integration indirectly affect operational performance by strengthening internal quality integration and AC. AC, evaluated through knowledge acquisition, assimilation, transformation, and exploitation, is pivotal in this process. The model highlights how external quality knowledge is assimilated and transformed into actionable insights, ultimately driving operational success. Using survey data from 264 pharmaceutical manufacturers, we applied Smart PLS to analyse the relationships. Our findings reveal the essential role of internal integration in translating and disseminating supply chain quality knowledge to enhance manufacturing capabilities. Effective communication, training, and collaboration facilitate the absorption of external insights, reinforcing operational performance. This research highlights the interconnected nature of quality integration practices across supply chain interfaces, emphasising that operational gains rely on first embedding external knowledge through internal quality integration. The originality and novelty of this study lie in uncovering a unique sequential mediation pathway, distinguishing it from prior research. By extending dynamic capability theory, we demonstrate how SCQI facilitates knowledge absorption through AC. Our findings challenge conventional views by positioning internal and external quality integration as synergistic dynamic capabilities, essential for driving superior operational performance.

Keywords: Quality management, Supply chain quality integration, Absorptive capacity, Dynamic capability. Pharmaceutical supply chains

Paper type: Empirical study

1. Introduction

Ensuring product and service quality remains a critical priority for organisations, yet maintaining high standards across increasingly complex supply chains continues to be a major challenge (Luo et al., 2023). Several studies have reported a significant rise in quality-related failures across global industries, particularly automotive, food, and pharmaceutical sectors (Cockrell et al., 2024; Tse et al., 2018). Notably, Tchonkouang et al. (2024) and Tse et al. (2018) extensively documented supply chain quality failures, highlighting the severe operational and financial risks associated with poor quality management. In the pharmaceutical sector, these risks are even more pronounced, as defective products can result in life-threatening consequences. Schleifenheimer and Ivanov (2024) highlighted the increasing frequency of quality issues, citing cases such as Merck & Co. Inc.'s $9 million penalty linked to fatalities caused by Vioxx (Narayana et al., 2014). Over the past five decades, the U.S. pharmaceutical sector alone has seen more than 75 drug recalls (Ghijs et al., 2024; Saroha et al., 2022), revealing persistent vulnerabilities in supply chain quality management. Furthermore, Johnson & Johnson's COVID-19 vaccine production disruption due to contamination at its Baltimore facility (Byttebier, 2022) and widespread cold chain failures (Line et al., 2020) further emphasise the fragility of pharmaceutical supply chains. A significant portion of these failures stems from deficiencies in supply chain (SC) transparency, coordination, and integration (Alkalha et al., 2019). These incidents collectively highlight the urgent need for robust Supply Chain Quality Integration (SCQI) frameworks to ensure harmonised quality practices across suppliers, customers, and internal operations (Van Nguyen et al., 2024; Cubo et al., 2023).

Addressing this critical gap, our study focuses on absorptive capacity (AC) as a pivotal enabler of SCQI, enhancing companies' ability to recognise, assimilate, and apply external knowledge to improve quality performance (Rodríguez-González and Madrid-Guijarro, 2023; Alkalha et al., 2019). AC supports dynamic capabilities by empowering organisations to sense emerging quality risks, seize relevant knowledge, and reconfigure internal resources to sustain compliance and competitiveness (Teece, 2019). Dynamic capability theory offers a valuable lens to understand how companies can achieve sustained advantage through continuous learning and adaptation, particularly in volatile and highly regulated environments like pharmaceuticals (Zighan et al., 2024). Within this context, AC operates as a dynamic capability by enabling companies to systematically integrate external quality knowledge from suppliers and customers, enhancing agility and resilience (Rodríguez-González and Madrid-Guijarro, 2023).

Despite growing recognition of SCQI's importance, several critical gaps remain in the literature. First, the specific mechanisms through which AC mediates the relationship between SCQI and operational performance are underexplored, especially in pharmaceutical supply chains (Huma et al., 2024; Akhtar et al., 2024). Second, while previous studies acknowledge SCQI's role in facilitating knowledge absorption, they have not examined the sequential mediation pathways. Specifically, how supplier and customer quality integration influence internal integration, which in turn activates AC to drive operational performance. Furthermore, there is insufficient empirical clarity on how SCQI and AC can be systematically leveraged to achieve operational excellence under regulatory pressure and market volatility (Schleifenheimer and Ivanov, 2024).

This study is original in its examination of the sequential mediation from supplier and customer quality integration through internal quality integration and absorptive capacity to operational performance, an area not sufficiently addressed in previous SCQI or AC research. By providing a multi-stage mediation model specific to pharmaceutical supply chains, the study offers a theoretical and practical contribution that clarifies the practical mechanisms through which external and internal quality integration efforts translate into operational excellence. Theoretically, the study extends dynamic capability theory by positioning AC as a central mechanism that mediates SCQI's effects on operational performance. By uncovering the sequential pathways, supplier and customer quality integration, internal quality integration, AC and operational performance, it offers a deeper understanding of how companies can adapt their quality management practices to dynamic market conditions. Practically, the study provides a roadmap for decision-makers in pharmaceutical and other high-risk industries on how to enhance collaboration, allocate resources more efficiently, and achieve operational excellence in the face of regulatory and market challenges.

Consequently, our study aims to investigate the sequential mediating impact of absorptive capacity (AC) on the relationship between supply chain quality integration (SCQI) and operational performance. We specifically answer the following research questions:

1. What is the mediating impact of absorptive capacity processes on SCQI operational performance?
2. In which pathways of SCQI and operational performance does absorptive capacity exhibit the most pronounced mediating influence?

This study adopts a quantitative research design to provide objective, replicable, and statistically robust insights. Using SmartPLS, we rigorously examine both direct and indirect effects to precisely identify where AC exerts its strongest mediating influence. A survey-based approach ensures that findings are generalisable across a broader population. The paper proceeds by outlining the theoretical framework, formulating hypotheses, presenting the empirical model, and discussing the key findings and their implications for both future research and industry practice.

2. Literature review

2.1 Theoretical Background and Conceptual Framework

In this study, dynamic capability theory is applied to illustrate how AC enables firms to sense, seize, and reconfigure quality-related knowledge from supply chain partners, thereby enhancing SCQI and improving operational performance (Teece, 2007). Sense refers to a firm ability to continuously scan their external environment to identify valuable knowledge. In the context of SCQI, AC plays a crucial role in recognising and assimilating external quality management practices, supplier expertise, and regulatory requirements (Teece et al., 2019; Laursen et al., 2010). This process ensures that firms remain proactive in addressing emerging quality risks in the pharmaceutical industry. Seizing refers to the ability of a firm to integrate effectively the relevant knowledge identified into its operations. Through AC, firms assimilate supplier and customer quality knowledge, fostering internal, supplier, and customer quality integration (Lin and Zhu et al., 2025). This alignment enhances collaboration and compliance with industry regulations, ensuring consistent quality performance across the supply chain (Zighan et al., 2024). Reconfiguring refers to the final stage of dynamic capability theory, which involve the transformation of knowledge into tangible improvements (Teece et al., 2019). AC enables firms to reconfigure their supply chain processes, upgrade quality management systems, and implement best practices, thereby strengthening SCQI (Zhao et al., 2023). This dynamic capability helps pharmaceutical firms enhance operational efficiency, reduce quality failures, and improve responsiveness to disruptions (Chowdhury and Quaddus, 2017). Thus, AC acts as the bridge that connects external insights, gathered from suppliers and customers, with internal operations (Lin and Zhu et al., 2025). Through its processes of scanning, filtering, and embedding knowledge into organisational routines, AC enhances companies' adaptability and responsiveness to dynamic supply chain environments (Elidjen et al., 2025). This dual role of AC aligns with dynamic capability theory by demonstrating how companies synchronise technical capabilities, such as internal quality and process alignment, with evolutionary capabilities, such as learning and adapting to external quality practices (Chowdhury and Quaddus, 2017).

Our study explores the mediating role of AC within SCQI pathways through our theoretical framework, focusing on how AC facilitates the integration of quality knowledge from suppliers and customers, enabling its internalisation through robust internal quality integration mechanisms (Zhao et al., 2023). By doing so, companies not only absorb external knowledge but also transform it into enhanced operational performance outcomes, such as quality, cost efficiency, delivery reliability, and flexibility (Alkalha et al., 2021; Teece et al., 2019). This aligns with the principles of dynamic capability theory, which emphasises the reconfiguration of organisational resources and processes to maintain competitiveness (Teece, 2007).

2.2 Supply Chain Quality Integration

Supply chain quality integration (SCQI) stems from supply chain integration in which supply chain integration is concerned with the overall operational efficiency and coordination, whereas SCQI specifically focuses on combining internal quality implementation with quality implementation across the SC to continuously develop the quality of products, services and processes (Zhang et al., 2017; Flynn et al., 2010). Huo et al., (2014b, p. 39) defined SCQI as "the degree to which an organisation's internal functions and external SC partners strategically and operationally collaborate with each other to jointly manage intra- and inter-organisational quality-related relationships, communications, and processes, to achieve high levels of quality-related performance at low costs". Alkalha et al., (2019) defined SCQI as a critical concept in supply chain management that emphasises the alignment and coordination of quality management practices across various partners in the supply chain. Effective SCQI enhances operational performance, customer satisfaction, and competitive advantage (Siddh et al., 2021). The majority of the recent studies have identified the essential components of SCQI, including internal quality integration, and external quality integration with suppliers and customers, as shown in Table (1).

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Internal quality integration refers to the alignment of quality management practices within an organisation (Huma et al., 2023). It involves fostering collaboration among different departments to ensure that quality standards are consistently met throughout the production process (Zhang et al., 2019). Huo et al. (2019) concluded that effective internal quality integration leads to improved communication and collaboration among teams, which enhances problem-solving capabilities and overall quality outcomes. In terms of external quality integration with suppliers, which is the other critical component of SCQI, involves establishing strong relationships with suppliers to ensure that the quality of inputs meets the required standards (Widiaswara et al., 2024). Akhtar et al., (2024) argued that effective supplier quality integration enhances trust and communication between organisations and their suppliers, leading to improved quality performance and reduced variability in the supply chain (Liu et al., 2023). Recent studies, such as that by Huma et al., (2023), have shown that organisations that actively engage in supplier quality integration are better positioned to manage quality-related risks and enhance their overall supply chain performance. Furthermore, external quality integration with customers is equally important for achieving SCQI. This component focuses on aligning quality management practices with customer expectations and requirements (Abdallah et al., 2021). According to Sharma and Joshi (2023), effective customer quality integration enhances customer satisfaction and loyalty by ensuring that products and services meet or exceed customer expectations. Kumar et al., (2023) concluded organisations that actively engage with customers to gather feedback and incorporate it into their quality management processes are more likely to achieve higher levels of operational performance.

2.3 Absorptive capacity

The importance of the AC process has grown significantly due to its critical role in fostering innovation and addressing complex challenges (Elidjen et al., 2025). Consequently, numerous studies have highlighted that AC is a core component of a company's dynamic capabilities, facilitating the acquisition and dissemination of knowledge (Sedoglavich et al., 2015; Hurtado-Palomino et al., 2022). Similarly, Zahra and George (2002) characterised AC as a dynamic capability that influences a company's ability to gather, integrate, and transform knowledge to create new capabilities through the processes of acquisition, assimilation, transformation, and exploitation. Similarly, Khachlouf et al. (2014, p.4) considered the AC as "a dynamic capability relating to knowledge creation and utilisation that enhances a firm's ability to gain and sustain a competitive advantage". Previous studies adopted different AC classification, as shown in Table (2). For instance, Riquelme-Medina et al. (2022) who measured AC by identifying value, and importing external knowledge, building internal routines to analyse the external knowledge, integrating new knowledge acquired from other entities, and exploiting newly integrated knowledge. Abourokbah et al. (2023) measured AC through digital capability, resilience, agility, and innovation. Later, Fuad et al. (2024) classified AC to exploitation and exploration knowledge. Recently, Lin and Zhu (2025) measured AC through companies' abilities to invest in research and development.

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However, the majority of previous studies adopted Zahra and George's (2002) model, who categorises absorptive capacity into four key components: acquisition, assimilation, transformation, and exploitation. Acquisition involves the processes through which organisations identify and acquire external knowledge that is significant to their operations (Alsmairat et al., 2023). Strong acquisition capabilities are better positioned to leverage external knowledge, particularly in rapidly changing industries (Elidjen et al., 2025). Assimilation refers to the processes through which organisations analyse their process, and understand the acquired knowledge (Huma et al., 2024). Zahra and George (2002) highlighted that assimilation involves integrating new information with existing knowledge structures, which is essential for effective decision-making and innovation.

Transformation involves the ability to convert acquired and assimilated knowledge into new products, processes, or practices (Patrucco et al., 2023). Zahra and George (2002) argued that transformation is critical for organisations to adapt to changing market conditions and leverage new knowledge effectively. Exploitation refers to the processes through which organisations utilise the transformed knowledge to improve their operations and achieve strategic objectives (Elidjen et al., 2025). Zahra and George (2002) emphasised that exploitation is essential for translating knowledge into tangible outcomes, such as improved products, services, and processes. Fuad et al. (2024), highlighted the importance of balancing exploration and exploitation to sustain efficiency and enhance their competitive advantage.

2.4 Operational performance

Operational performance is a critical aspect of organisational success, encompassing various dimensions such as efficiency, quality, cost, delivery, and flexibility, see Table (3). Operational performance reflects how well an organisation utilises its resources to produce goods and services while meeting customer expectations (Machingura et al., 2024).

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Recent studies have highlighted the importance of operational performance in achieving competitive advantage and sustaining growth in dynamic market environments. Whilst previous studies measure the operational performance through quality, cost, flexibility, and delivery (Brendt et al., 2024; Gu et al., 2023). Quality is a vital dimension of operational performance, as it directly impacts customer satisfaction and loyalty. Lee et al., (2024) demonstrated the importance of a digital supply chain in enhancing the quality of products. Cost performance is often considered a primary component of operational performance, focusing on the optimal use of resources to minimise waste and maximise output (Oliveira-Dias et al., 2025). According to Al-Dweiri et al. (2024) and Minshull et al. (2022), organisations that implement lean manufacturing practices can significantly enhance their operational efficiency. Delivery performance refers to the ability of an organisation to meet customer delivery expectations, including lead times and reliability (Oliveira-Diaset al., 2025). Agyei-Owusu et al. (2022) highlighted the importance of supply chain integration in improving delivery performance. Garcia-Buendia et al. (2023) indicates that organisations that invest in flexible manufacturing systems can better respond to fluctuations in demand and improve their competitive positioning. As a result, flexibility is increasingly recognised as a crucial component of operational performance, particularly in volatile markets (Gu et al., 2023).

2.5 The pharmaceutical supply chains

Product quality is essential for pharmaceutical companies to protect companies' reputations and competitiveness (Nagurney et al., 2013). Meanwhile, companies face challenges of reducing costs and improving product quality, delivery and flexibility; therefore, understanding SCQI is important (Chen et al., 2020; Alkalha et al., 2024). Nevertheless, the supply chain in the pharmaceutical industry faces problems with product recall, outdated SC strategies, and poor inventory control (Tayyab et al., 2022). Thus, developing dynamic capabilities through AC to implement SCQI is necessary in the pharmaceutical industry (Tayyab et al., 2022; Alkalha et al., 2019). For instance, Kuwaiti companies lack the knowledge of dealing with medical disposals (Abahussain et al., 2012; Alshemari et al., 2020). In 2010, Taiji Industry Company initiated a product recall for the slimming product "Qumei" due to its inclusion of the prohibited ingredient "Sibutramine," known to pose risks of cerebrovascular and cardiovascular diseases in humans (Zhao et al., 2013). Rafique et al. (2019) highlighted that pharmaceutical companies need to deal with the challenge of learning and using new information from various sources. Quality problems in the pharmaceutical supply chain can have significant implications for public health and safety (Alkalha et al., 2019). One of the common challenges is the occurrence of fake drugs, where falsified medications infiltrate the supply chain, putting patients at risk. For instance, the World Health Organisation (WHO) has highlighted instances of counterfeit antimalarial drugs containing insufficient or no active ingredients (WHO, 2020). Additionally, further deviations in manufacturing processes often contribute to product recalls, impacting both the reputation of pharmaceutical companies and the well-being of consumers (WHO, 2020). These examples emphasise the critical importance of maintaining high-quality standards throughout the pharmaceutical supply chain to ensure the efficacy and safety of medications (Alkalha et al., 2019).

2.6 The development of the hypotheses

Organisations increasingly recognise the critical role of supply chain knowledge in navigating dynamic market environments (Polater, 2024). According to dynamic capability theory, companies must continuously sense opportunities, seize resources, and reconfigure processes to maintain competitiveness (Teece, 2007). Within this theoretical framework, AC emerges as a vital enabler, facilitating the development of both technical and evolutionary activities that underpin dynamic capabilities (Chatterjee et al., 2022). AC processes, acquiring, assimilating, and applying external knowledge, empower organisations to identify shifts in market demands, respond strategically, and transform their operations to enhance performance (Teece et al., 2019; Laursen et al., 2010). Technical activities, supported by AC, focus on embedding quality across internal functions and processes. These activities enable firms to sense and respond to quality-related challenges, ensuring the seamless integration of cross-functional quality efforts (Abou-Foul et al., 2023). For example, AC allows organisations to sense opportunities in supplier and customer relationships, assimilate knowledge about quality standards, and reconfigure internal processes to align with these insights (Herold and Marzantowicz, 2023; Huo et al., 2014b). This integration enhances operational performance dimensions such as quality, delivery, cost efficiency, and flexibility by facilitating streamlined processes and improved communication across SC members (Salam and Bajaba, 2023). Conversely, evolutionary activities involve leveraging external knowledge to adapt to broader environmental changes (Teece et al., 2019). AC plays a central role in evolutionary activities by enabling organisations to sense external trends, seize valuable insights from SC partners, and reconfigure their external and internal resources for continuous improvement (Najafi et al., 2013). By fostering collaborative learning with suppliers and customers, AC strengthens the company’s ability to adapt to changing regulations, technological advancements, and market demands (Khraishi et al., 2023). These processes ensure that firms remain agile and competitive, particularly in the implementation of quality practices that improve products and services (Calvo et al., 2015).

Dynamic capability theory highlights the importance of AC as a bridge between technical and evolutionary activities, allowing firms to align internal and external quality integration (Abou-Foul et al., 2023). This theoretical perspective underscores the role of AC in facilitating continuous learning and adaptation, which is essential for effective SCQI. Internally, AC facilitates the cross-functional dissemination of knowledge to embed quality deeply into operations. Externally, it supports the assimilation of insights from suppliers and customers, enabling firms to integrate this knowledge into their strategic and operational frameworks (Alkalha et al., 2019; Alkalha et al., 2024). For instance, Liu et al., (2009) highlight that AC enhances visibility, shared values, and coordinated plans, fostering agility and responsiveness. Moreover, Alkalha et al., (2019) demonstrated that AC processes help firms reconfigure their production systems, improving operational outcomes across quality, cost, delivery, and flexibility. Building on this understanding, the study hypothesises that AC acts as a mediating mechanism through which SCQI drives operational performance improvements. Thus, the following hypotheses were developed:

> H1a: Absorptive capacity positively and significantly mediates the relationship between internal quality integration and quality performance.
> H1b: Absorptive capacity positively and significantly mediates the relationship between internal quality integration and cost performance.
> H1c: Absorptive capacity positively and significantly mediates the relationship between internal quality integration and delivery performance.
> H1d Absorptive capacity positively and significantly mediates the relationship between internal quality integration and flexibility performance.

To successfully integrate SCQI and enhance operational performance, companies must develop a comprehensive quality strategy that overcomes barriers to customer and supplier collaboration (Luo et al., 2020). However, the link between SCQI and operational performance is not straightforward and typically necessitates a configurational approach, where the extent of SCQI implementation is contingent upon the absorptive capacities of the companies (Alkalha et al., 2019; Danese and Bortolotti, 2014). Previous studies have emphasised that AC plays a pivotal role in fostering dynamic capabilities, allowing companies to sense, seize, and reconfigure resources to achieve superior SC integration and operational performance (Fayard et al., 2012). Companies can sense critical knowledge from customers and suppliers, such as market trends, demand patterns, and production solutions (Manzoor et al., 2022). Also, the knowledge is seized by leveraging this knowledge to generate new ideas and strategies, while reconfiguring focuses on embedding these insights into operational processes to enhance performance outcomes (Engelmann, 2024). Companies build strong connections with SC partners through effective AC processes, increasing visibility, minimising information asymmetries, and fostering knowledge sharing to improve integration and operational performance (Qiao and Zhao, 2023). For instance, AC's ability to sense and assimilate customer feedback enables companies to adapt processes, reducing costs and improving delivery reliability (Huo et al., 2014b). Conversely, supplier integration's impact on delivery and flexibility performance may be limited due to spatial and structural barriers (Wiengarten and Longoni, 2015).

Dynamic capability theory offers a structured framework for understanding these processes. By developing AC as a dynamic capability, companies enable technical activities, such as embedding quality practices across functions, and evolutionary activities, such as reconfiguring resources to align with changing market conditions (Abou-Foul et al., 2023). AC helps firms integrate supplier knowledge into internal quality practices, facilitating the translation of external insights into improved product quality, cost efficiency, and flexibility in production systems (Khraishi et al., 2023). Additionally, AC enhances companies' abilities to reconfigure their operational resources to adapt to changing customer needs, ensuring agility, delivery reliability, and sustained competitive advantage (Najafi et al., 2013). Moreover, Alkalha et al., (2019) demonstrated that SCQI practices, supported by AC, facilitate knowledge management, improving firms' capabilities to maintain product and process quality. Companies with robust AC leverage SC knowledge to sense opportunities, seize insights, and reconfigure resources to generate value (Fynes et al., 2015). Therefore, the following hypotheses were developed:

H2a: Absorptive capacity positively and significantly mediates the relationship between customer and internal quality integration and quality performance.
H2b: Absorptive capacity positively and significantly mediates the relationship between customer and internal quality integration and cost performance.
H2c: Absorptive capacity positively and significantly mediates the relationship between customer and internal quality integration and delivery performance.
H2d: Absorptive capacity positively and significantly mediates the relationship between customer and internal quality integration and flexibility performance.

H3a: Absorptive capacity positively and significantly mediates the relationship between supplier and internal quality integration and quality performance.
H3b: Absorptive capacity positively and significantly mediates the relationship between supplier and internal quality integration and cost performance.
H3c: Absorptive capacity positively and significantly mediates the relationship between supplier and internal quality integration and delivery performance.
H3d: Absorptive capacity positively and significantly mediates the relationship between supplier and internal quality integration and flexibility performance.

Prior studies highlight that AC enables companies to sense customer-derived knowledge, such as specific needs, preferences, and expectations, which is critical for driving improvements in product quality and responsiveness to market changes (Luo et al., 2023; Huo et al., 2014). This capacity to sense knowledge helps companies identify opportunities for innovation and improvement in their operations (Manzoor et al., 2022). Once customer insights are sensed, AC facilitates the seizing of these insights by transforming them into actionable strategies that address customers' needs and reduce inefficiencies, such as waste in production and delivery processes (Qiao and Zhao, 2023). By leveraging AC, companies can create processes that align more closely with customer demands, thereby enhancing customer satisfaction and competitive advantage (Abou-Foul et al., 2023).

The reconfiguration aspect of AC ensures that companies integrate and institutionalise customer-derived knowledge into their operational and strategic frameworks. This enables companies to adapt their delivery systems and production capabilities dynamically, improving not only product quality but also delivery reliability and flexibility (Zhang et al., 2017). Through this reconfiguration, companies develop the agility needed to respond effectively to evolving customer requirements and market conditions (Alkalha et al., 2019). Consequently, AC serves as a key driver of technical activities, such as refining delivery processes to reduce waste, and evolutionary activities, such as continuously adapting operational capabilities to align with customer feedback and market trends (Chowdhury and Quaddus, 2017). Thus, the following hypotheses were developed:

H4a: Absorptive capacity positively and significantly mediates the relationship between customer quality integration and quality performance.
H4b: Absorptive capacity positively and significantly mediates the relationship between customer quality integration and cost performance.
H4c: Absorptive capacity positively and significantly mediates the relationship between customer quality integration and delivery performance.
H4d: Absorptive capacity positively and significantly mediates the relationship between customer quality integration and flexibility performance.

Through AC, companies gain the ability to identify and extract valuable knowledge from suppliers, such as advanced production methods, innovative materials, and process enhancements (Wu et al., 2022). This sensing capability is essential for uncovering opportunities to enhance product quality and eliminate operational inefficiencies (Alkalha et al., 2021). Seizing follows sensing, where AC allows companies to translate supplier insights into actionable strategies (Teese et al., 2019). By leveraging this knowledge, organisations can incorporate supplier expertise into their quality practices, fostering improved alignment and operational efficiency (Richey et al., 2022). The ability to seize such opportunities ensures that companies not only recognise but also fully capitalise on the potential of supplier collaborations to drive quality improvements (Alsawafi et al., 2021). By reconfiguring resources is a critical function of AC, enabling companies to adapt and institutionalise supplier-derived practices within their operational systems (Teese et al., 2019). This reconfiguration allows companies to continuously refine their processes, resulting in better flexibility, enhanced delivery performance, and sustained quality advancements (Mirza et al., 2023). By dynamically aligning their operations with supplier knowledge and evolving market demands, companies are better equipped to respond to environmental changes and maintain a competitive edge in their supply chains (Abou-Foul et al., 2023).

By underpinning the role of AC's within supplier quality integration to dynamic capability theory we highlight the importance in driving technical advancements, such as embedding quality standards into workflows, and evolutionary activities, like adapting to new supplier insights and shifting conditions (Salam and Bajaba, 2023; Manzoor et al., 2022). This highlights the transformative power of AC in enhancing collaboration, operational efficiency, and overall supply chain performance (Alkalha et al., 2021). Therefore, the following hypotheses were developed:

> H5a: Absorptive capacity has a positive and significant mediating role in the relationship between supplier quality integration and quality performance.
> H5b: Absorptive capacity has a positive and significant mediating role in the relationship between supplier quality integration and cost performance.
> H5c: Absorptive capacity has a positive and significant mediating role in the relationship between supplier quality integration and delivery performance.
> H5d: Absorptive capacity has a positive and significant mediating role in the relationship between supplier quality integration and flexibility performance.

3. Methodology

3.1 The research framework

The study framework, as depicted in Figure (1), illustrates the mediating role of AC in the relationship between SCQI and operational performance**.** Based on the hypotheses developed in the previous section, the framework demonstrates how AC facilitates the assimilation and transformation of external quality knowledge into actionable insights, driving improvements in key performance areas such as quality, cost, delivery, and flexibility. The sequential model outlined in the framework reflects the interconnected nature of these relationships, highlighting how the absorption of external knowledge, when effectively integrated internally, leads to enhanced operational outcomes.

--Insert Figure 1 Approximately Here---------------------------

3.2 Data collection

We designed a comprehensive questionnaire based on the theoretical foundations of dynamic capabilities and supply chain integration literature. For data collection, a survey method was utilised, which is commonly employed in social science research to yield accurate and reliable results (Neuman, 2013). The questionnaire underwent a rigorous validation process in three stages: an initial review by three supply chain management scholars, a focus group discussion with 10 academic experts to gain practical insights, and an additional review by 10 professionals in the pharmaceutical industry to refine the clarity and relevance of the questions. The pilot test led to adjustments in the survey, simplifying and shortening the terminology. This thorough development process ensured the tool's reliability and validity.

We employed a random sampling technique to ensure a representative sample from different levels of the pharmaceutical supply chain. Companies were randomly selected and contacted via email from a “global database.” A total of 1,000 questionnaires were distributed (see the appendix), with supply chain managers as the primary respondents. The unit of analysis was the company level, with one respondent from each company. In total, 310 completed questionnaires were returned, but 46 were excluded due to incomplete data. Therefore, the final sample consisted of 264 valid responses, resulting in a response rate of 26.4%, which exceeds the acceptable threshold of 20% (Malhotra and Grover, 1998).

3.3 Measures

The study hypothesises a five-step sequential mediation model**,** whereby customer and supplier quality integration indirectly drives operational performance through the amplification of internal quality integration and AC. AC, measured through its components of knowledge acquisition, assimilation, transformation, and exploitation, acts as a critical mechanism in this pathway. This model highlights the dynamic interplay between the integration of external quality knowledge and its internal assimilation and transformation into actionable insights, ultimately enhancing operational outcomes.

The data was analysed using Smart PLS, a widely recognised software application for Partial Least Squares Structural Equation Modelling (PLS-SEM) (Wong, 2013). PLS-SEM was chosen due to its advantages over traditional covariance-based SEM techniques, particularly in handling complex causal relationships, formative and reflective constructs (Lowry and Gaskin, 2014**).** Unlike covariance-based SEM software such as AMOS or LISREL, which require large sample sizes - especially for mediation analysis, where a sample size above 350 is needed to ensure statistical power and robust estimations - Smart PLS is more flexible and remains effective regardless of the sample size (Sim et al., 2022; Hair et al., 2014). Smart PLS also provides advanced analytical capabilities, such as multi-group analysis making it ideal for assessing the sequential mediation pathways examined in this study (Cheah et al., 2023)**.** Therefore, Smart PLS is the most appropriate tool for this study's objectives, enabling a comprehensive examination of the relationships between absorptive capacity, internal quality integration, and operational performance. The measures showed an accepted factor loading above 0.60 (Comrey and Lee, 2013), as shown in Figure (2).

---Insert Figure 2 Approximately Here----------------------------

The convergent validity was calculated for scale validation (Hair et al., 2010). As shown in Table (4) the value of the average variance extracted (AVE) for all variables is exceeded 0.5. This means that all the constructs are good representations of the concepts. Also, the table shows that the composite reliability for all variables is above .70. This means that the indicator variables loading on the latent variable have shared variance among them

---Insert Table 4 Approximately Here----------------------------

The discriminant validity is as depicted in Table (5) where all variables have discriminant validity in which the square root of AVE for all variables is greater than the correlation between any pair (Hair et al., 2010)

---Insert Table 5 Approximately Here----------------------------

Moreover, as per Table (6) the model revealed a good fit with SRMR < .08 and the normed fit index (NFI) is above 0.90 threshold (Sivo *et al.*, 2006).

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4. Results

This section presents the outcomes of the structural model assessment, focusing on the mediating role of absorptive capacity (AC) in the relationship between different dimensions of supply chain quality integration (SCQI) and operational performance. The evaluation is based on path coefficients and effect sizes (f^2), following Hair et al.'s (2010) scale: values ≥ 0.5 denote large effects, values around 0.3 indicate medium effects, and values ≤ 0.1 reflect small effects. Table (7) provides the detailed statistical results.

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Path 1: Internal Quality Integration → AC → Operational Performance

The results show that AC significantly mediates the link between internal quality integration and all operational performance dimensions, quality, cost, delivery, and flexibility, with medium effect sizes (f^2 = 0.274, 0.246, 0.264, 0.282; $P < 0.05$). These findings validate H1a–H1d, highlighting internal integration as a pivotal enabler of knowledge transformation. This indicates that companies with robust internal collaboration and cross-functional alignment are better positioned to absorb, process, and exploit quality-related knowledge, thereby enhancing multiple operational capabilities simultaneously.

Path 2: Customer quality integration → Internal quality integration → AC → Operational Performance

Next, the model reveals a positive and statistically significant mediation of AC in the relationship between customer and internal quality integration and all operational outcomes, albeit with small effect sizes ($f^2 = 0.139, 0.125, 0.134, 0.143$; $P < 0.05$), supporting H2a–H2d. While the indirect effects are weaker than those from internal integration, the consistent significance across all performance metrics confirms that customer-facing quality inputs, such as complaint data, feedback, and regulatory expectations, are valuable sources of innovation, especially when internally aligned through effective knowledge absorption mechanisms.

Path 3: Supplier quality integration → Internal quality integration → AC → Operational Performance

Similarly, the analysis supports H3a–H3d, showing that AC significantly mediates the relationship between supplier and internal integration and performance, with smaller but still significant effects ($f^2 = 0.066, 0.059, 0.063, 0.067$; $P < 0.05$). These results point to a more limited role for supplier-driven quality knowledge, suggesting that such inputs may be underutilised or less easily absorbed due to inter-organisational complexities, weaker data transparency, or varying quality standards.

Path 4: Customer quality integration → AC → Operational Performance

A more prominent role of AC emerges when mediating the relationship between direct customer quality integration (bypassing internal mediation) and operational outcomes. This pathway displays medium effect sizes ($f^2 = 0.280, 0.251, 0.269, 0.287$; $P < 0.05$), supporting H4a–H4d. The findings underscore the strategic value of real-time customer engagement, especially in pharmaceutical contexts where responsiveness to patients, providers, and regulators can directly influence drug efficacy, compliance, and service delivery.

Path 5: Supplier quality integration → AC → Operational Performance

In contrast to expectations, AC did not significantly mediate the relationship between supplier quality integration and operational performance. The path coefficients were negative and statistically insignificant ($f^2 = -0.017, -0.015, -0.016, -0.017$; $P > 0.05$), leading to the rejection of H5a–H5d. This finding suggests that supplier-derived knowledge may be either insufficiently transferred or poorly assimilated within the firm's operational structure. It may also reflect contextual barriers in the pharmaceutical industry, such as strict supplier confidentiality, IP protection, or lack of trust, which inhibit effective knowledge sharing and exploitation.

Taken together, these results reveal a clear pattern of performance improvement driven by the combination of internal quality integration and absorptive capacity. The most substantial gains are achieved when customer insights are effectively embedded within internal processes or directly leveraged via AC. Conversely, the unexpectedly weak or negative role of supplier quality integration highlights a potential area of risk or inefficiency that may require targeted managerial interventions. Overall, our analysis demonstrates that operational excellence in the pharmaceutical sector is not merely a function of integration with supply chain partners but hinges critically on the companies' ability to internalise and act upon external knowledge inputs. The mediating role of AC emerges as a crucial dynamic capability that enables this transformation, aligning with the theoretical foundations of the study.

5. Discussion

5.1 General discussion

This study investigates the mediating impact of AC on the relationship between SCQI and operational performance**.** Rooted in the dynamic capability framework, the study proposed a nuanced pathway where both internal and external quality integration enhance operational efficiencies by fostering knowledge absorption and application. The motivation behind this investigation stems from the pharmaceutical industry's demand for high operational standards**,** which are continually tested by rapid technological change, evolving customer expectations, and strict regulatory requirements. The result empirically validates the central role of AC as a sequential mediator linking SCQI to operational performance**.** For instance, the data showed that internal quality integration significantly enhances AC**,** and this in turn leads to improved performance across quality, cost, delivery, and flexibility. This mediating structure advances the dynamic capabilities literature by confirming that the ability to assimilate and exploit external knowledge is not guaranteed, it depends on the configuration and maturity of internal systems.

The result stresses that the way pharmaceutical companies design and implement internal quality integration directly influences how effectively they build AC. For instance, companies with structured internal quality systems and well-integrated cross-functional processes are better equipped to translate external insights into operational gains. This aligns with Dultra and Brito (2023) and Honarpour et al. (2018), who asserted that the success of knowledge-sharing practices is rooted in internal knowledge management capabilities. Furthermore, the study demonstrates the strong and direct effect of customer quality integration on AC. In contrast to prior assumptions**,** the findings indicate that customer-derived knowledge can enhance operational performance even when internal quality integration is only partially developed. This diverges from previous studies (e.g., Luo et al., 2023; Abdallah et al., 2021), which posited internal integration as a necessary precursor to customer knowledge utilisation. Our result suggests that in pharmaceutical companies, customer knowledge may be captured through alternative channels, such as digital feedback systems or dedicated customer relationship teams, bypassing the need for full internal integration. This is particularly relevant in an industry where customer knowledge is often technical, regulatory, or clinical in nature, dimensions that may be directly utilised without extensive internal coordination. As discussed by Albort-Morant et al. (2018), the nature of knowledge (tacit vs. explicit) affects how it is absorbed. Likewise, Kumar et al. (2023) suggested that companies may rely on complementary mechanisms like R&D, CRM systems, or data analytics to interpret and use customer insights. These insights explain why internal quality integration is not always indispensable for customer knowledge exploitation in this context. However, the result of this study indicates that supplier quality integration only contributes meaningfully to AC when strong internal quality systems are in place, which supports the idea that supplier knowledge is often technical, complex, and interdependent, requires well-developed internal routines for effective assimilation. Therefore, our results suggest the path from supplier integration to operational performance is indirect and relies heavily on the intermediary role of internal quality integration and AC. This layered mediation highlights the knowledge-intensive nature of pharmaceutical operations and highlights the importance of aligning supplier collaborations with internal capability development. As demonstrated by Alkalha et al. (2019), AC plays a central role in enabling companies to adapt to scientific advancements, regulatory changes, and new technologies, which are core challenges in pharmaceutical environments.

Taken together, the results identify a robust sequential mediation pattern: supplier quality integration → internal quality integration → AC → operational performance. This pathway supports a strategic model of operational improvement where companies first build internal capabilities, then absorb supplier knowledge, and finally apply it to refine production, reduce errors, and enhance service delivery**.** This confirms the pharmaceutical industry's systematic approach to continuous improvement and resilience (Akhtar et al., 2024; Tayyab et al., 2022). Ultimately, the study offers a novel theoretical and empirical contribution by uncovering how pharmaceutical companies can combine SCQI dimensions and AC to achieve sustained operational excellence.

5.2 Theoretical Contribution

This study makes an original contribution by addressing a critical conceptual gap in the existing literature on SCQI and AC, namely, the lack of clarity on how these constructs interact in a sequential and interdependent manner to influence operational performance. While previous research has acknowledged the importance of SCQI and AC independently (e.g., Zighan et al., 2024; Akhtar et al., 2024**)**, few studies have conceptually or empirically unpacked the mechanistic pathways through which different forms of quality integration (supplier, customer, and internal) are connected and collectively contribute to capability development and performance improvement. Moreover, the novelty of this study lies in demonstrating, with empirical evidence, that internal quality integration plays a bridging role, transforming externally sourced quality knowledge (from customers and suppliers) into organisational routines that enhance AC. This challenges prior conceptualisations that implicitly treated internal, customer, and supplier quality integration as functionally equivalent or independent. Our findings reveal a conceptual hierarchy: external integration efforts alone are insufficient without a robust internal integration layer that enables knowledge assimilation and application via AC.

Additionally, this study highlights that the effectiveness of SCQI is contingent on the absorptive mechanisms that mediate its influence on performance, a conceptual nuance that is often overlooked in the literature, where AC is treated as a static construct or a parallel enabler. By showing that AC is not uniformly activated by all quality integration sources, evidenced by its insignificant mediating role in the supplier quality integration pathway, this research adds conceptual depth by identifying boundary conditions for the AC–SCQI link. Additionally, our study offers a novel contribution to dynamic capability theory by empirically demonstrating how AC, activated through SCQI, enables both technical and evolutionary activities in pharmaceutical operations. It shows that internal quality integration facilitates the technical dimension of dynamic capabilities, helping companies seize and exploit external knowledge through standardised processes, regulatory compliance, and operational efficiency. Simultaneously, customer and supplier quality integration supports the evolutionary dimension by enabling companies to sense external changes and reconfigure internal routines in response to market demands, regulatory shifts, and innovation opportunities. Unlike prior studies that examined SCQI and AC in isolation, this research uniquely models and validates a sequential pathway where external quality integration enhances internal integration, which in turn builds AC and leads to improved operational performance. This transformation translates the abstract elements of dynamic capability theory, sensing, seizing, and reconfiguring, into actionable mechanisms grounded in quality management practice.

In summary, this study makes a distinct theoretical contribution by unveiling and validating a previously untested sequential mediation model that links SCQI and AC within the operational core of pharmaceutical companies. It extends dynamic capability theory to explain how quality integration practices evolve into adaptive, knowledge-based capabilities, capable of sustaining performance under complexity and regulatory pressure. These insights not only enrich theoretical discourse but also offer evidence-based guidance for building dynamic operational capabilities in high-stakes supply chains.

5.3 Practical Contribution

This study delivers targeted, data-driven insights that directly support pharmaceutical supply chain decision-making. Based on empirical evidence, the findings emphasise how different quality integration pathways, namely customer, supplier, and internal, vary in their impact on operational performance, with AC acting as a pivotal mediator. Our analysis indicates that internal quality integration significantly enhances operational outcomes by leveraging AC, notably improving quality, delivery , flexibility, and cost performance. This suggests that pharmaceutical companies should prioritise enhancing cross-functional alignment, synchronising quality objectives across departments, and embedding quality-centric routines into core operational processes. Investment in real-time quality analytics, standardised SOPs, and cross-training programs emerges as a high-impact intervention for strengthening internal coherence and agility. While customer quality integration also contributes meaningfully, especially in enhancing flexibility and responsiveness, the result highlights the importance of leveraging healthcare provider feedback and pharmacovigilance data to inform adaptive manufacturing and post-market improvements. Feedback loops from clinicians and regulators, when systematically processed through AC mechanisms, provide a valuable resource for quality innovation and risk mitigation.

In contrast, supplier quality integration demonstrates limited or insignificant effects on operational performance when mediated by AC. This finding underscores a critical gap in how pharmaceutical companies currently engage with upstream suppliers. Rather than relying predominantly on compliance audits, our analysis suggests the need for more integrative practices—such as collaborative co-development initiatives, long-term strategic partnerships, and transparent performance metrics—to effectively embed supplier insights into internal learning processes. Our study further emphasises the strategic importance of AC across all domains. AC is not merely a technical construct but a dynamic capability that enables companies to transform external and internal knowledge into actionable process improvements. Managers should prioritise building this capacity through formal knowledge management systems, cross-boundary collaboration, and continuous learning initiatives that span the entire value chain. From a managerial standpoint, this research provides clear, actionable guidance for aligning quality integration efforts with specific operational goals, whether reducing costs, enhancing delivery reliability, or improving responsiveness. The differentiated effect sizes across integration types equip decision-makers with a nuanced understanding of where to allocate resources, how to structure quality initiatives, and which functions to prioritise for capability development.

Importantly, these managerial improvements have broader implications beyond operational metrics, directly influencing public health outcomes. Strengthening quality integration, particularly in internal and customer-facing processes, contributes directly to the production and delivery of safe, effective pharmaceuticals. By reducing the incidence of recalls, non-compliance, and production inefficiencies, the study supports not only organisational resilience but also ethical, patient-centred practices that safeguard healthcare outcomes. In sum, this research bridges theory and practice by translating complex interactions between integration types, AC, and performance into specific, empirically validated recommendations. It provides a roadmap for pharmaceutical companies seeking to enhance operational excellence while advancing public health and regulatory integrity.

6. Conclusions, implication and future work

This study uncovers the central role of AC in mediating the relationship between different forms of SCQI and operational performance in pharmaceutical supply chains. The study found that internal quality integration acts as a critical enabler that transforms external quality inputs from both customers and suppliers into AC. This, in turn, significantly enhances performance across quality, cost, delivery, and flexibility dimensions. Our results imply that customer quality integration has a consistently strong influence on AC development, suggesting that close alignment with customer needs and expectations fosters effective knowledge absorption and application. This partially mediates the path to performance improvement, indicating that while internal quality integration strengthens this effect, customer-driven knowledge can still enhance operations even without full internal mediation. On the other hand, supplier quality integration alone did not significantly influence AC or operational performance unless supported by strong internal quality practices. This highlights the importance of robust internal quality integration as a foundation for interpreting and utilising supplier knowledge. Only when internal mechanisms are mature can companies convert supplier inputs into meaningful performance gains. Overall, the results extend existing literature by empirically validating a sequential mediation structure where external integration (with customers and suppliers) feeds into internal quality processes, which then drive AC and ultimately improve operational outcomes. This clearly demonstrates that AC is not an isolated capability but is deeply embedded within the quality integration infrastructure of the firm, especially in high-complexity environments like pharmaceuticals. These findings enrich the current understanding of dynamic capability theory by showing that internal quality integration supports both technical learning and evolutionary learning, making AC a dynamic mechanism for operational resilience and innovation.

While our study offers valuable insights into supply chain dynamics within the pharmaceutical industry, several limitations warrant discussion and open avenues for future inquiry. First, we used a cross-sectional design, it captures relationships at a single point in time. While our findings clearly show that internal quality integration helps turn supplier and customer knowledge into AC, which then improves performance in areas like cost, quality, delivery, and flexibility, we were not able to track how these relationships change or develop over time. Future research using a longitudinal approach could offer deeper insights into how SCQI and AC evolve and work together in the long run to strengthen operational resilience and support ongoing innovation. Secondly, while our analysis confirmed the positive mediating role of AC in most quality integration-performance linkages, it also revealed an unexpected finding: the mediating role of AC in the supplier quality integration pathway was statistically insignificant and negative. This divergence suggests that not all sources of external knowledge contribute equally to AC development or operational performance, a conceptual nuance often overlooked in prior research. Future research should further investigate these asymmetries, perhaps by differentiating between transactional and collaborative supplier relationships or by incorporating contextual moderators such as trust, power dynamics, or technological alignment.

Additionally, our reliance on self-reported measures introduces the risk of response bias, especially since data were collected from single informants. Although our structural model explained a high proportion of variance in key performance variables, future research could validate these findings through triangulation with objective performance indicators (e.g., defect rates, cost savings, service levels) or multi-respondent data. This would provide a stronger empirical foundation for understanding how AC operationalises SCQI in real-world settings. Whilst, our findings are grounded in the pharmaceutical sector, where regulatory complexity and product criticality uniquely shape quality practices, we offer depth in a highly regulated sector, it may constrain the generalisability of our model to other regulated sectors, such as healthcare and nuclear. Future research should apply and test this sequential framework in other high-complexity or innovation-driven industries, such as aerospace, medical devices, or semiconductors, to assess whether the same hierarchical quality integration mechanisms and absorptive pathways apply. This would help determine the boundary conditions of our results and strengthen the external validity of SCQI-AC theory development. Ultimately, our study implicitly surfaced the importance of knowledge infrastructure and digital capability as enablers of internal integration and AC. Future research should explicitly examine how technologies like AI, blockchain, and advanced analytics moderate the SCQI–AC–performance relationship. These tools may either enhance or replace traditional integration mechanisms, thereby reshaping the way firms acquire, assimilate, and exploit external knowledge. By incorporating digitalisation into future models, researchers can extend the applicability of our framework and ensure that theory keeps pace with the evolving technological landscape of global supply chains.

Competing Interests Statement

The authors declare that they have no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

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Table

Table 1. The components of SCQI in previous studies

Previous studies	SCQI's components
Akhtar et al.(2024)	Supplier quality integration, customer quality integration
Widiaswara et al.(2024)	Supplier quality
Huma et al.(2023)	Supplier quality integration, customer quality integration, internal quality integration
Sharma and Joshi (2023)	Quality strategy, leadership and integration
Liu et al.(2023)	Quality events
Kumar et al.(2023)	Leadership, customer focus, training, employee relation
Abdallah et al.(2021)	Supplier quality integration, customer quality integration, internal quality integration
Siddh et al.(2021)	Supplier quality integration, customer quality integration, internal quality integration
Zhang et al.(2019)	Supplier quality integration, customer quality integration, internal quality integration
Yu et al.(2019)	Supplier quality integration, customer quality integration, internal quality integration

Source: Developed by authors.

Table 2. The components of AC in previous studies

Previous studies	AC's components
Lin and Zhu (2025)	The ratio of annual R&D investment to operating income
Elidjen et al.(2025)	Knowledge acquisition, assimilation, transformation, exploitation
Fuad et al.(2024)	Exploration and exploitation
Huma et al.(2024)	Knowledge acquisition, assimilation, transformation, exploitation
Asamoah et al.(2024)	Knowledge acquisition, assimilation, transformation, exploitation
Rodríguez-González et al.(2023)	Knowledge acquisition, assimilation, transformation, exploitation
Abourokbah et al.(2023)	Digital capability, resilience, agility, innovation
Patrucco et al.(2023)	Knowledge acquisition, assimilation, transformation, exploitation
Alsmairat et al.(2023)	Knowledge acquisition, assimilation, transformation, exploitation
Riquelme-Medina et al.(2022)	Identify value, and import external knowledge, internal routines to analyse the external knowledge Integrate new knowledge acquired from other entities, exploit newly integrated knowledge

Source: Developed by authors.

Table 3. The components of operational performance in previous studies

Previous studies	Operational performance's components
Oliveira-Dias et al.(2025)	Efficiency, delivery
AL-Khatib (2025)	Delivery, flexibility, production and transportation cost
Al-Dweiri et al.(2024)	Quality performance, inventory management
Lee et al.(2024)	Quality, productivity, cost
Chatha et al.(2024)	Quality, delivery, flexibility, design
Machingura et al.(2024)	Quality, cost, delivery, flexibility, lead time
Berndt et al.(2024)	Quality, cost, delivery, flexibility, lead time, speed to introduce new products/services
Gu et al.(2023)	Quality, cost, delivery, flexibility
Garcia-Buendia et al.(2023)	Quality, delivery, flexibility, cycle time
Agyei-Owusu et al.(2022)	Quality, cost, delivery, flexibility

Source: Developed by authors.

Table 4. Construct reliability and validity

The variable	Composite reliability	Average variance extracted (AVE)
AC	0.835	0.663
C.QINT	0.812	0.636
Cost	0.938	0.848
Delivery	0.808	0.717
Flexibility	0.805	0.680
I.QINT	0.723	0.630
Quality	0.950	0.905
S.QINT	0.853	0.660

Source: Developed by authors.

Table 5. Disarmament validity

	AC	C.QINT	Cost	Delivery	Flexibility	I.QINT	Quality	S.QINT
AC	0.814							
C.QINT	0.672	0.798						
Cost	0.599	0.479	0.921					
Delivery	0.641	0.633	0.451	0.847				
Flexibility	0.685	0.599	0.530	0.716	0.824			
I.QINT	0.670	0.651	0.410	0.457	0.492	0.793		
Quality	0.667	0.676	0.523	0.686	0.647	0.544	0.952	
S.QINT	0.448	0.598	0.396	0.555	0.410	0.543	0.626	0.813

Source: Developed by authors.

Table 6. Model fit

	Measures
SRMR	0.072
Chi-Square	1143.260
NFI	0.934

Source: Developed by authors.

Table 7. Hypotheses Test

Path	Indirect effects	P-Value	Hypotheses	Accepted/Rejected
I.QINT -> AC -> Quality	0.274	0.000	H1a	Accepted
I.QINT -> AC -> Cost	0.246	0.000	H1b	Accepted
I.QINT -> AC -> Delivery	0.264	0.000	H1c	Accepted
I.QINT -> AC -> Flexibility	0.282	0.000	H1d	Accepted
C.QINT -> I.QINT -> AC -> Quality	0.139	0.000	H2a	Accepted
C.QINT -> I.QINT -> AC -> Cost	0.125	0.001	H2b	Accepted
C.QINT -> I.QINT -> AC -> Delivery	0.134	0.000	H2c	Accepted
C.QINT -> I.QINT -> AC -> Flexibility	0.143	0.001	H2d	Accepted
S.QINT -> I.QINT -> AC -> Quality	0.066	0.016	H3a	Accepted
S.QINT -> I.QINT -> AC -> Cost	0.059	0.026	H3b	Accepted
S.QINT -> I.QINT -> AC -> Delivery	0.063	0.012	H3c	Accepted
S.QINT -> I.QINT -> AC -> Flexibility	0.067	0.022	H3d	Accepted
C.QINT -> AC -> Quality	0.280	0.001	H4a	Accepted
C.QINT -> AC -> Cost	0.251	0.000	H4b	Accepted
C.QINT -> AC -> Delivery	0.269	0.002	H4c	Accepted
C.QINT -> AC -> Flexibility	0.287	0.000	H4d	Accepted
S.QINT -> AC -> Quality	-0.017	0.661	H5a	Rejected
S.QINT -> AC -> Cost	-0.015	0.665	H5b	Rejected
S.QINT -> AC -> Delivery	-0.016	0.662	H5c	Rejected
S.QINT -> AC -> Flexibility	-0.017	0.664	H5d	Rejected

Source: Developed by authors.

Appendix: The survey

Please answer the following questions.

Please select to what extent you agree/disagree with the following statements.

Customers' quality integration. Chen and Paulraj (2004) and Huo et al. (2014) .

No	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	Your company focus on working with the most important customers to improve their abilities to preserve the products' quality	○	○	○	○	○
2	Your customers are actively involved in your product design process/product.	○	○	○	○	○
3	Your company is frequently in close contact with your customers in terms of continuously investigating the agents'/pharmacies' ability to protect the products' quality	○	○	○	○	○
4	Your company gives training to the agents' employees and the key pharmacists	○	○	○	○	○

Suppliers' quality integration. Adapted from: Miocevic and Crnjak-Karanovic (2012), and Huo et al. (2014).

No	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
5	Your company works with key suppliers to improve their quality performance in the long run.	○	○	○	○	○
6	Your company maintains close communications with suppliers about quality considerations and design changes	○	○	○	○	○
7	Your company has a strategic partnership with suppliers (E.g. royalty rights, technical transfer, license)	○	○	○	○	○
8	Your company collaborates with suppliers in improvement activities for new raw materials and products/processes (E.g. training, co-development)	○	○	○	○	○

Internal quality integration. Adapted from: Huo et al. (2014) and Wong et al. (2011).

No	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
9	In your company standardised procedures exist for product and process, transfers between different units or sites, which ensure a fast, stable, and complied process	○	○	○	○	○
10	The functions in your company cooperate to solve conflicts between them when they arise	○	○	○	○	○
11	During problem-solving, the top management in your company makes an effort to get all team members' opinions and ideas before making a decision.	○	○	○	○	○

Absorptive capacity .Adapted from: Soo et al. (2016) and Zhang et al. (2015).

No	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
12	Your company has a special mechanism to gain knowledge from supply chain (e.g. consumer behaviour, production knowledge, feedback) in real time.	○	○	○	○	○
13	Your company has a specific policy to periodically link the existing knowledge with new knowledge	○	○	○	○	○
14	Your company's system and procedures have enough ability to use the new knowledge to quickly modify and improve the products and the processes	○	○	○	○	○
15	Your company applies new knowledge acquired from supply chain to critical competitive needs and use this knowledge in problem-solving	○	○	○	○	○

Operational performance. Adapted from: Wong et al. (2011) and Huo et al. (2014).

No	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	Products quality					
16	Your company is able to produce consistent quality products with low defects	○	○	○	○	○
17	Your company offers high reliable products that meet customers need	○	○	○	○	○
18	Your company's products quality is less than competitors	○	○	○	○	○
	Cost of production					
19	Your company is able to produce products with low costs comparing with competitors	○	○	○	○	○
20	Your company offers price as low or lower than your competitors	○	○	○	○	○
21	Your company has high percentage of internal error and rework	○	○	○	○	○
	Delivery					

22	Your company is able to deliver correct quantity with the right quality kind of products	○	○	○	○	○
23	Your lead time for fulfilling customers' orders (the time which elapses between the receipt of customer's order and the delivery of the goods) is short comparing with competitors	○	○	○	○	○
24	Your company has an outstanding on-time delivery record to your main customer.	○	○	○	○	○
	Flexibility					
25	Your company can quickly modify products to meet your main customers' requirements.	○	○	○	○	○
26	Your company is first in the market in introducing new products comparing with competitors	○	○	○	○	○
27	Your company has time-to-market longer than industry average	○	○	○	○	○

Figure

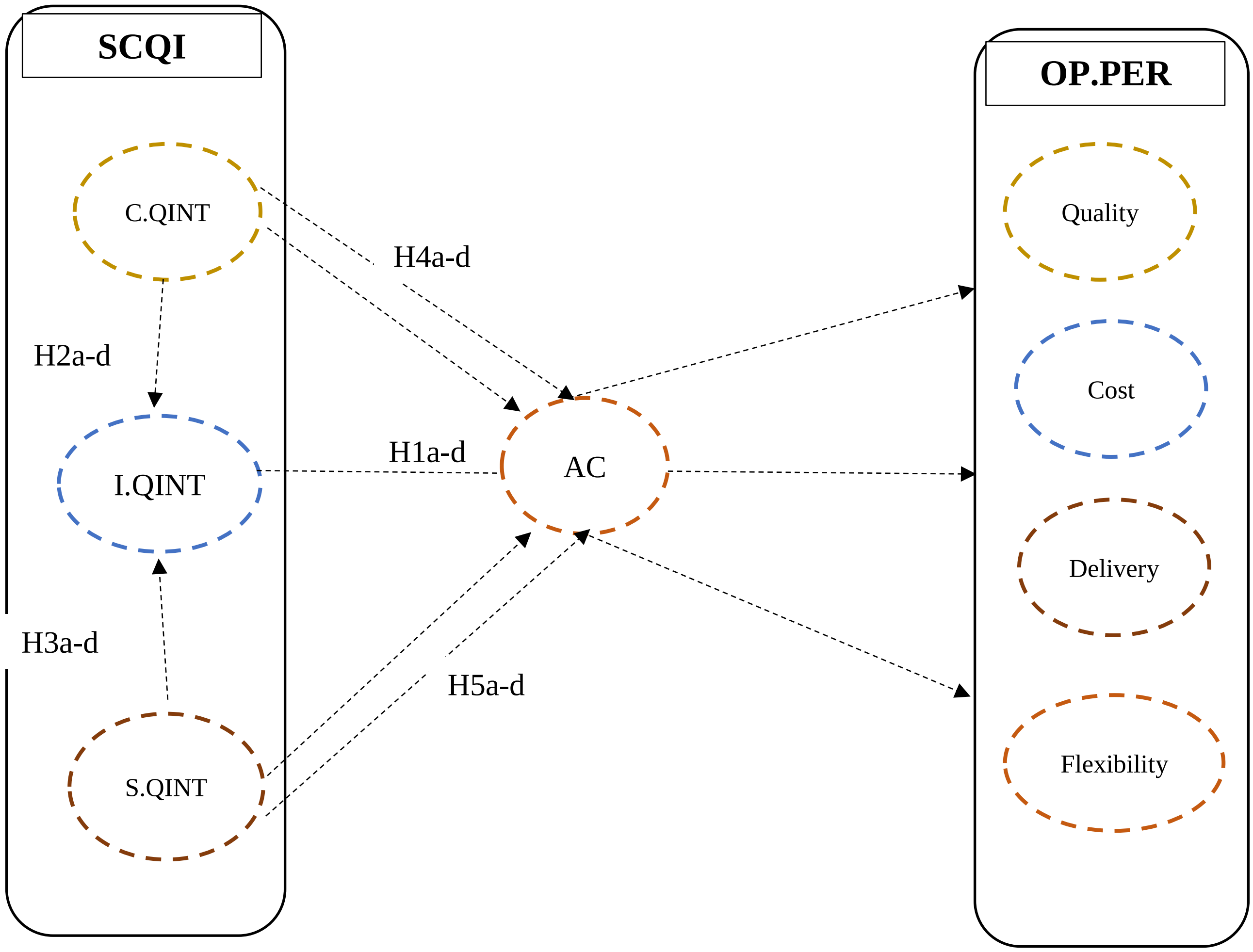

Figure 1 AC impact on SCQI and operational performance

Source: Developed by authors.

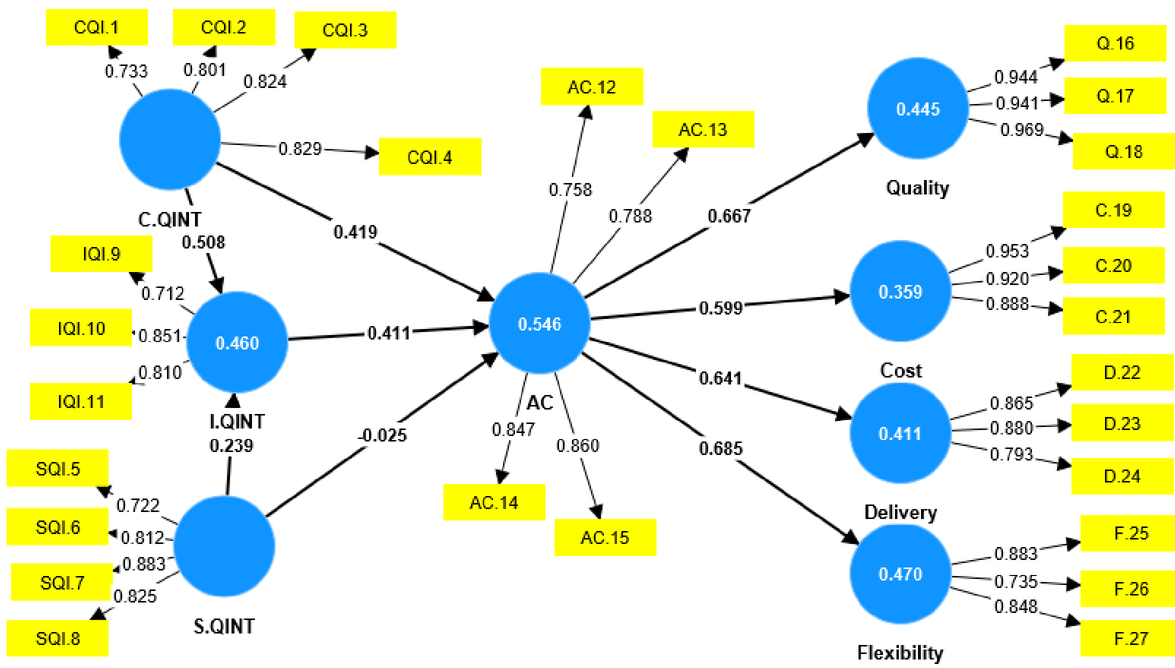

Figure 2 The Study Model

Source: Developed by authors.

The Journal of Operations Management Research.

Dear Prof. Eric H. Grosse,

I am writing regarding our submission **OMRA-D-24-00298R2** entitled " How Absorptive Capacity Mediates Supply Chain Effectiveness: A Quality Integration Approach to Boosting Operational Performance ". First of all, I would like to thank you for giving us fruitful feedback, which helped in improving the paper. Also, thank you for giving us a chance to re-submit the paper after making the required amendments. Thus, we confirm that we accepted all reviewers' comments and did our best to work on these comments. All the required changes were highlighted in Yellow. However, we have also worked hard on the whole paper, paying attention to presentation and grammar. etc. (although not highlighted in Yellow). Please find our response as follows:

Comments for the Author:

AE: The reviewers are now generally favorable, and your paper can be considered for publication, subject to some further minor but important revisions:

Please check the structure and section numbering throughout the paper. For example, add a subsection 5.1 on page 18 for your general discussion. Also, note that Section 6.1 is unnecessary if there is no corresponding Section 6.2.

Response: Thank you for the comment. We have checked and reviewed the structure of the paper as required.

Sections 5 and 6 have improved but still read somewhat generically. It is important that you specifically reflect on your individual findings and the data analyzed when discussing the implications of your work, both for managers and for future research. Additionally, you should revisit the state of the art (your literature review) and clearly articulate the novelty of your results compared to related published literature.

Response:

Thank you for the comment. In section 5 and 6 we have rewritten aspects in line with these (Highlighted in Yellow). We believe these targeted revisions clearly address your concerns by explicitly anchoring our discussion and implications in the specific empirical findings. Specifically, the contribution and implications for managers and future research, highlighting a conditional mediation pathway in our data, demonstrating that pharmaceutical firms can effectively leverage customer-derived knowledge even without fully developed internal integration differentiating our work from existing literature, and offering clear, actionable directions for both managerial practice and future scholarship.

Try to generally avoid repetition and overly generic language in the discussion.

Response: Thank you for the comment. Yes we have streamlined section to avoid repetition.

The content on limitations and future research can be integrated into the theoretical contributions section, as there is currently some redundancy. Be sure to reflect on the real contribution your work makes to existing theory, not just its novelty.

Response: Thank you for the comment. We have built on the analysis and discussion to discuss our contribution in section 5 and have integrated the limitation in section 6.

Finally, Section 4 is currently very brief and does not adequately reflect the richness of your data.

Response: Thank you for the comment. We have developed section 4 around 5 key paths (highlighted in yellow) where we report on the model findings.

Finally, we would like to thank the reviewers for their constructive feedback and comments. We have worked diligently to address them and enhance the quality, flow and clarity of the manuscript. We look forward to hearing from you.

Kind Regards,

The authors