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Supply Chain Management Through Cloud Computing in the Retail Sector

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ABSTRACT

In this study, the effect of cloud computing on supply chain management efficiency and performance within China's retail sector is investigated. Based on survey data of 400 retail sector managers and Partial Least Squares Structural Equation Modeling (PLS-SEM), the study finds that the cloud integration, data accessibility, and real-time analysis significantly improve supply chain efficiency, therefore improving supply chain performance. Though it directly enhances performance, it does not moderate the efficiency-performance curves. Findings show that cloud computing is an important technology to help retailers operate more efficiently, more quickly and have a competitive advantage, regardless of company size. Through these contributions, the research provides useful insights to practitioners and policymakers about how to optimally exploit cloud computing in support of increasing the strategic value of the retail supply chain in China.

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1. Introduction

The retail sector grew exponentially in the last decades to become one of the biggest and most transformational sales sectors in the world economy. While this phenomenon is observed in many parts of the world, it is particularly significant in China given the rapid economic development, urbanization, rising disposable income and digitalization of the country (Liu et al., 2024; Yang, Shafiq, Sharif, et al., 2024; Zhang, 2024). The retail sector made up nearly 30 percent of China's GDP in 2021, according to the report by the National Bureau of Statistics of China, and it represents an essential part of the sustained economic development of China. However, great challenges have been brought to this sector supply chain management (SCM) as well, due to which retailers tend to find ways to improve the efficiency, responsiveness and competitiveness (Zhang & Wei, 2019).

As customers' demands are soaring, the market competition is getting fiercer, and omni-channel further elevates the pace of technology advancement in the retail industry, the retail supply chain management has become more complex (Yang, Shafiq, Nazir, et al., 2024; Zhou et al., 2023). Retail supply chains in China are facing many challenges, such as inefficient data management, weak real-time data analytics capability, fragmented logistics systems, environmental issues, and lack of collaboration among stakeholders (Chen, 2024; Fan, 2023). The inefficiencies indicated above manifest directly in terms of high inventory costs, late product delivery, poor forecast of inventory, health, and massive wastage of resources with a negative impact on the competitiveness and profitability of retail businesses (Farooq, Abbey, et al., 2024; Wang, 2023). Despite the challenges involved, Chinese retailers urgently need innovative approaches to maintaining robust SCM performance through better efficiency and responsiveness (Zhou et al., 2023).

The emergence of cloud computing as a promising solution to many forthcoming SCM challenges by offering scalable, flexible and cost-effective technological resources for optimizing supply chain operation (Chakraborty & Das, 2020; Wu et al., 2019). The use of cloud technologies allows real-time data integration, collaborative decision-making, better scope of visibility within supply chains, and rapid quickness to market dynamics (Boutkhoum et al., 2017; Kudirat Bukola et al., 2024). Studies from developed countries show the substantial benefit that cloud computing can bring to SCM in the form of efficiency enhancements, better inventory management, agility and cost reductions (Farooq, Wu, et al., 2024). Nevertheless, with global evidence demonstrating that cloud computing has a sizeable positive impact, adoption and application of cloud computing in the retail sector of China in the literature are relatively underexplored and thus represent a large research gap (Wang et al., 2018).

Prior studies predominantly investigated cloud computing’s general impacts in manufacturing and logistics contexts, with limited empirical evidence explicitly targeting the Chinese retail sector. On the other hand, there is inadequate empirical clarity about how cloud computing contributes to the efficiency and performance of SCM in the context of China’s retail environment (Cheng et al., 2024; Wang et al., 2018). Further, little research has sought to understand how firm size or retail scale affects the relationship between supply chain efficiency through the cloud and total supply chain performance (Noshad et al., 2019; Zhou et al., 2023). Thus, the importance from an in-depth perspective made an intense study especially related to the role that this type of cloud computing can contribute to improve SCM efficiency and performance as well as the moderating effect of the retail scale in China's retail businesses.

These aims can be of theoretical and practical contributions. The research is a theoretical extension of the current SCM literature because it puts a particular country (China), as well as a particular industry (diverse retail industry) into perspective to establish and refine the knowledge of cloud computing adoption and manages to fill several crucial gaps in theoretical understanding. Lastly, it contributes to existing knowledge about the strategic importance of cloud computing through its investigation of how its combination, access to data and real-time intelligence would impact the efficiencies and performance outcomes within the retail environments.

This research will aim at exploring the benefits of cloud computing in enhancing the performance of the supply chain management (SCM) in the retail sector especially in China. Such as, it specifically examines the impact of cloud integration on the overall efficiency of the supply chain, the impact of the data access that cloud computing provides on the operational efficiency, and how the real-time capability of cloud systems to perform the overall supply chain responsiveness. Secondly, the study has another purpose in evaluating the direct relationship between the retail scale (size) of companies and the supply chain performance and investigating whether the retail scale can moderate the relationship between the supply chain efficiency and the overall performance. The study aims at seeking answers to these objectives to provide an insight into the way cloud computing technologies can be utilized effectively by retail organizations and policymakers to deliver more superior SCM results.

The results of this study have significant implications on Chinese retailers and policymakers. The insights gained through empiricism can be extremely useful to the retail managers when making decisions on the way they can engage cloud computing in their business to increase supply chain efficiency, responsiveness, and competitive advantage. In addition to this it is also necessary to appreciate the moderating effect of firm size in developing such targeted strategies towards large- and small-scale retailers to best allocate and invest in cloud infrastructure. Policy makers could also use insights of this research in ensuring that technology is adopted in the retail sector of China in a conducive regulatory environment, and incentive policies.

Also, the work is a direct response to the national strategic interest of digital transformation and innovation led growth established in the state of Made in China 2025 and Dual Circulation (State Council of China, 2020). It also fits in with the national initiatives to modernize the traditional sectors in China with the help of digital technology and, therefore, has a positive impact on the overall economic objectives of China. With Chinese retail markets constantly swelling in the rate at which they become more competitive, it is important to gain understanding of how cloud computing may be employed to enhance the efficiency and performance of SCM not only to individual firms, but the economy at large.

Overall, the significant expansion and sophistication of the Chinese retail industry serve as the reason to emphasize the urgent need to find new technological solutions to make the supply chains more efficient and overall improve the performance of the industry. In view of the current theoretical and empirical gaps on cloud computing adoption, and this is in the retail environment in China, this research aims at making valuable contributions in the SCM literature with strategic implications on practitioners and policy makers. Through the thorough analysis of the direct effects of cloud computing and the moderating influence of the scale of the retail business, this study is a timely reaction to the most imperative needs of the industry and academia, facilitating the further increase in growth, innovation, and efficiency in the Chinese retail environment.

The rest of the paper is organized as follows: Section 2 presents all the literature review in a critical way, discussing the existing research and developing hypotheses connected with the integration of cloud computing, data accessibility, real-time analysis, efficiency of supply chain, retail scale, and the overall performance of supply chain. Section 3 outlines research methodology, which includes research design, data collection methodology, measurement tool and methods of data analysis. Section 4 argues out and discusses the empirical results of the analysis. These findings are addressed in Section 5 concerning previous research and theoretical points of view. Then, the concluding remarks, the practical implications, the limitations of the research and the future research recommendations are presented in Section 6.

2. Literature Review

This part entails critical review of the available body of knowledge on the constructs examined in this research with clear focus on the role of cloud computing in modifying the performance of SCM within the retail industry. With the continuously growing competitive environment and the growing digital interconnectedness of the retail settings, cloud technologies are becoming the current disruptive power on the optimization of the supply chain process. In this, we have the Chinese retail market environment of rapid technological implementation and rapid consumers that provide an interesting environment to consider these relations.

The literature has been divided into six major subsections according to an alternate construct of the suggested conceptual framework. The first three subsections providing their interrelations are the independent variables which are Cloud Integration, Data Accessibility and real-time analysis which are what drive Supply Chain Efficiency. The Retail Scale and Supply Chain Efficiency were both assessed as having a direct influence on the Supply Chain Performance, which in turn is discussed in the two subsequent subsections using the knowledge gained in the above. The final sub-section examines the moderation effect of Retail Scale on efficiency-performance relationship.

Each sub-section synthesizes theoretical backgrounds, empirical results and methodology of past studies to uphold the hypotheses of the research. Besides emphasizing the significance of each construct, such an organization of the review also indicates areas of critical research that will be required to contribute to our knowledge in the emergent markets in China, such as in the strategic adoption of cloud technologies. Lastly, six testable hypotheses can be formulated based on the developed conceptual model in the literature that has been reviewed in this section.

2.1. Cloud Integration and Supply Chain Efficiency

Cloud integration is also being perceived as a necessity to enhance efficiency of the supply chain by enhancing its connectivity, flexibility and operational agility. Earlier studies emphasize that cloud technologies make communication smoother, facilitate collaborative planning, and real-time data sharing across the supply chains (Boutkhoum et al., 2017; Chakraborty & Das, 2020). According to Prajapati, Gupta, et al. (2024), cloud computing allows companies to conduct advanced analytics and use resources more effectively. Gunasekaran and Ngai (2004) also came to the similar conclusion that incorporation of cloud-based solutions enhances the accuracy and responsiveness of inventory. Also, other research papers by Sanders (2007) and Al-Sharafi et al. (2023) have helped to substantiate the argument that cloud integration can, in fact, shorten lead times, and operational risks, which enhances efficiency in the supply chain significantly. Moreover, reported that cloud computing can increase the level of scalability and lessen the level of information asymmetry, which leads to significant operational efficiencies in the retail supply chains (Al-Sharafi et al., 2023; Khayer, Jahan, et al., 2020; Şener et al., 2016). Therefore, based on the insights from the above cited literature, we formulate our first research hypothesis as:

H1: Cloud Integration has a positive impact on Supply Chain Efficiency.

2.2. Data Accessibility and Supply Chain Efficiency

The availability of data plays a crucial role in effective supply chain management, which has a significant influence on the responsiveness of operations, transparency, and collaboration. Croson and Donohue (2003) argue that data sharing enhances the effectiveness of the bullwhip within a supply chain and stabilizes inventory changes, which leads to more efficiency in the supply chain. Wu et al. (2019) showed the way blockchain technology enhances the accessibility of the data by maintaining data integrity and sharing them in a timely manner. According to Gopal et al. (2022), improved access to real-time data optimizes forecasts and minimizes uncertainties leading to the ultimate efficiency of operations. The accessibility of the data is increased through cloud-based systems, which contribute to the faster decision-making process and minimizes disruptions (Arunachalam et al., 2018; Çorak et al., 2018; Sadiq et al., 2024; Sanders, 2007). Loureiro et al. (2018) also reported notable positive effects of enhanced flow of information with the help of the ERP and neural network technologies on the performance of the supply chain and stated inaccessibility of data as one of the key efficiency enablers. Consequently, based on the understandings from the above-mentioned works, we articulate our second research hypothesis as:

H2: Data Accessibility positively influences Supply Chain Efficiency.

2.3. Real-Time Analysis and Supply Chain Efficiency

Real-time analysis is a game changer because it enables organizations to quickly react to the changes in the market dynamics and therefore improves supply chain efficiency. According to Kudirat Bukola et al. (2024) and Muthukalyani (2024), IoT-based real-time analytics is also essential in offering better visibility, transparency, and agility throughout the supply chain. Because real-time analytics forecast demand better, handle inventory more efficiently, and improve the accuracy of decisions, Holloway (2024) points out that there is a direct link between operational efficiency and the analytics. Shang et al. (2010) affirmed the role played by real-time data analytics in promoting the collaboration of suppliers, reducing operational risks and enhancing strategic partnerships. Research by Muthukalyani (2024) and (Holloway, 2024) additionally highlights the difficulties in deploying real-time analytics like data security, complexity of integration, yet also attests to the significant improvements in long-term efficiency of the implementation when properly handled. These findings highlight the importance of the real-time analytics capacity to become excellent in supply chains. Thus, based on the understandings from the above-mentioned research, we develop our third research hypothesis as:

H3: Real-Time Analysis positively impacts Supply Chain Efficiency.

2.4. Retail Scale and Supply Chain Performance

The size of the firm or retail level has a significant influence on the performance of the supply chain, which either affects the allocation of resources, adoption of technology, and the responsiveness to market fluctuations. Roespinoedji et al. (2019) established that bigger companies usually attain better supply chain performance because of the increased resources, integration ability, and more technology adoption (Wang et al., 2024). Lee (2019) emphasized that bigger retailers are much better off with economies of scale as they have demonstrated better outcomes of operational and environmental performance. In the same manner, Wiengarten et al. (2012) and Flynn et al. (2009) reaffirmed that bigger companies use lean practices and quality management in a better manner to increase overall supply chain performance. Also, Roh et al. (2022), Gawankar et al. (2013), (Kot et al., 2018) and Awan et al. (2022) each separately supported the positive and direct association between the size of the retail firm and improved operational performance, competitive advantage, and market responsiveness, which validated the importance of firm size in the effectiveness of the supply chain. Consequently, based on the understandings from the above-mentioned works, we articulate our next research hypothesis as follows:

H4: Retail Scale has a positive direct impact on Supply Chain Performance.

2.5. Supply Chain Efficiency and Supply Chain Performance

The efficiency of the supply chain has a direct impact on the overall performance of the supply chain and the higher the efficiency of the supply chain, the greater the responsiveness, lower costs and customer satisfaction. Abdallah et al. (2014) discovered that there exists strong relationship between effective supply chain practices, including internal integration and effective information sharing, and high operational outcomes. This has been supported by Bruque-Cámara et al. (2016) who pointed out that lean and efficient processes greatly boost performance of operations. At least, Zelbst et al. (2012) and Danese and Romano (2011) claimed that the efficiency improvement brought by such technologies as RFID has a substantial impact on responsiveness and operations disruption. Dehgani and Jafari Navimipour (2019) also confirmed that effective information and communication processes are key in improving the supply chain agility. Holloway (2024) and Kudirat Bukola et al. (2024) studies have continuously highlighted the direct and significant positive effect of enhanced efficiency on the performance of supply chains in terms of sustainability, profitability, and market performance. The work cited above enables us to develop next hypothesis for this paper as:

H5: Retail Scale moderates the relationship between Supply Chain Efficiency and Supply Chain Performance, such that the positive relationship is stronger for larger-scale retailers.

2.6. Moderating Effect of Retail Scale on Supply Chain Efficiency and Supply Chain Performance

Firm size or retail scale significantly moderates the relationship between supply chain efficiency and performance. Larger firms generally possess more substantial resources, enabling better leverage of efficiency enhancements into meaningful performance improvements (Yang & Wang, 2022). According to Cook et al. (2011), the improved efficiency literature shows that larger firms can extract more value from the efficiency improvements because they have sophisticated infrastructure, higher levels of strategic flexibility and superior resource capabilities. For instance, Chetthamrongchai and Jermsittiparsert (2019) also show that firm size moderates the effectiveness of improving efficiency, particularly in sustainable supply chain practices. The constraint in resources and capabilities by the SMEs, as articulated in Shibin et al. (2017) and Arunachalam et al. (2018), suggests that efficiency gains often do not translate into large performance outcomes for the SMEs. On the other hand, larger enterprises, however, are capable of greatly magnifying the benefits gleaned from supply chain efficiencies through the higher level of adoption of technology, corresponding implementation of strategy and associated judicious deployment to enhance their overall competitive edge. That is why, we postulate the next research hypothesis for the current study given below:

H6: Supply Chain Efficiency positively influences Supply Chain Performance.

The conceptual framework proposed outlines the mechanisms by which cloud-capabilities enhance the outcomes in the retail supply chain setting. Cloud Integration, Data Accessibility and Real-Time Analysis are hypothesized as fundamental technological drivers of Supply Chain Efficiency (SCE). In China, where the retail sector is fast becoming digitalized (through massive scale e-business), omnichannel stores and data-driven activities, cloud integration enables the smooth coordination of suppliers, warehouses, and retail shops. Increased data accessibility increases the level of information transparency across the supply chain, and real-time analysis is the basis of demand forecasting, inventory optimization, and agile decision-making. These technological capabilities, when combined, strengthen the supply chain efficiency, which subsequently has a positive effect on Supply Chain Performance (SCP) in the form of enhanced responsiveness, cost savings, service quality, and customer satisfaction. Furthermore, Retail Scale is theorized as a direct predictor of supply chain performance as well as a mediating variable that enhances the SCESCP relationship, suggesting that bigger retailing companies in China have a greater opportunity to exploit cloud-based efficiencies to deliver high-quality performance results. In general, the framework emphasizes cloud computing as a strategic facilitator of the contemporary supply chain management in the dynamic Chinese retail sector.

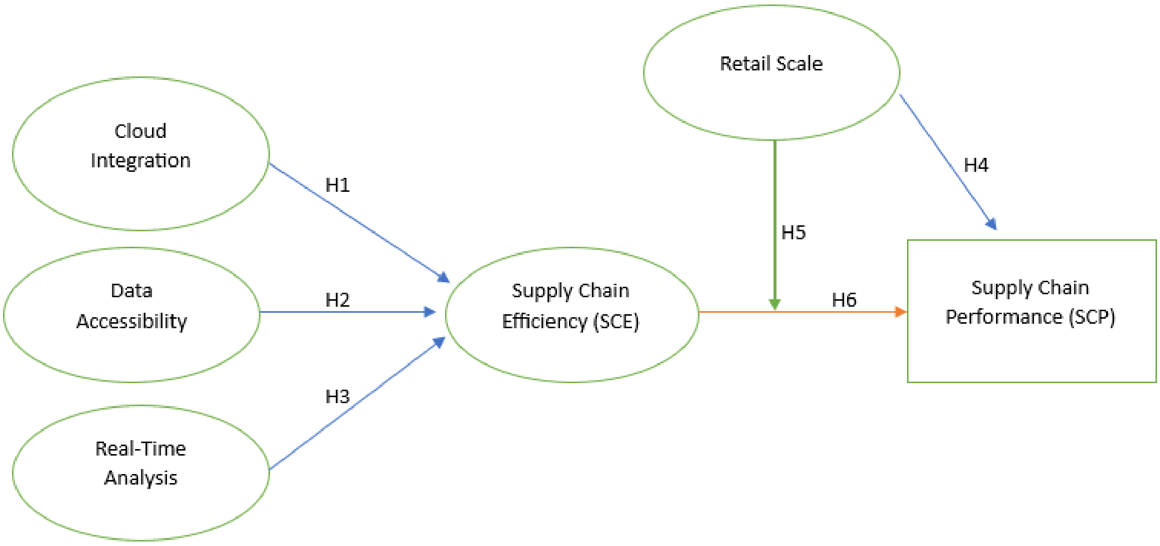

Figure 1: Conceptual Framework: The Impact of Cloud Computing on Supply Chain Efficiency and Performance in the Retail Sector

3. Methodology

3.1. Research Design

A quantitative research design using a survey approach was used in this study to determine the relation between cloud computing factors with supply chain performance by way of supply chain efficiency, and the relations were moderated by retail scale in the Chinese retail sector. To test hypotheses in the studies having complex relationship between many variables, the primary data is collected by a structured questionnaire (Khayer, Bao, et al., 2020). Thus, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed, which can be used as a means of exploratory research and also handle complex models of mediation and moderation (Nazir et al., 2023; Sarstedt et al., 2022).

3.2. Population and Sampling Procedure

Managers involved in supply chain management activities in the Chinese retail business sector formed the target population for this research. Researchers selected study participants from a target population of managers who act as supply chain management practitioners in Chinese retail operations and have experience with both supply chain management and cloud computing applications. A total of 400 survey respondents match the recommended sample requirements of PLS-SEM analysis according to (Sarstedt et al., 2022). The selected sample will serve adequately analyzing relationships between variables and confirming theoretical predictions.

3.3. Measurement

The questionnaire consisted of validated measurement items adapted from existing literature to ensure reliability and validity. Cloud Integration (CI) was measured by using three items adapted from Low et al. (2011), and Data Accessibility (DA) was measured through three items derived from Oliveira et al. (2014). Real-time analysis (RTA) comprised five items adapted from the studies by Jayapaul (2024), Ngai et al. (2011), and Tarannum and Hossain (2024). The mediating variable, Supply Chain Efficiency (SCE), is measured by ten items adapted from studies by Fawcett and Magnan (2002), DeGroote and Marx (2013), Gunasekaran and Ngai (2004), Sanders (2007), and Tallon and Pinsonneault (2011). Retail Scale (RS), serving as a moderator, included four categorical items adapted from Storey (2016), Ailawadi et al. (2010), and Burt et al. (2003). Finally, Supply Chain Performance (SCP) was measured by five items adapted from recent studies by Al-Khatib (2023), Bag et al. (2023), and Al-khatib et al. (2024). All items were rated on a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), except for Retail Scale, measured categorically (Small, Medium, Large).

Table 1
Constructs, Number of Items, Scale, and Sources

Construct	Number of Items	Adapted From
Cloud Integration (CI)	3	Low et al. (2011)
Data Accessibility (DA)	3	Oliveira et al. (2014)
Real-Time Analysis (RTA)	5	Jayapaul (2024), Ngai et al. (2011), and Tarannum and Hossain (2024)
Supply Chain Efficiency (SCE)	10	Fawcett and Magnan (2002), DeGroote and Marx (2013), Gunasekaran and Ngai (2004), Sanders (2007), and Tallon and Pinsonneault (2011)
Retail Scale (RS)	3	Storey (2016), Ailawadi et al. (2010)
Supply Chain Performance (SCP)	5	Al-Khatib (2023), Bag et al. (2023), and Al-khatib et al. (2024)

3.4. Data Analysis Technique

Because PLS SEM provides robustness in managing large models with many latent components and moderating effects, when modeling data, Smart-PLS software version 4.0 (Hair et al., 2019) was used. It was accomplished through two phases of analysis — validation of measurement model and specification of structural model. In addition, the assessment of measurement validity included reliability (Cronbach's alpha, composite reliability), convergent validity (average variance extracted), and discriminant validity (HTMT and Fornell-Larcker criteria) (Hair et al., 2019). Bootstrapping was carried out with 5000 iterations to estimate the statistical significance of the process and to assess the structural models. A path analysis was performed to evaluate hypothesized linkages and moderating effects.

Also, Cronbach alpha and CR values of 0.70 or more and AVE values greater than 0.50 (Hair et al., 2019) corresponded to the reliability and validity of the constructs. Discriminant validity was also demonstrated owing to HTMT ratios above the threshold value of 0.85, which is believed to be the best cutoff point for evaluating different constructs (Hair et al., 2019).

3.5. Ethical Considerations

The research maintained high ethical standards during its serious scientific execution. Every participant gave their free consent after receiving full information. The study conducted all activities through anonymous and confidential means, so participant data remained beyond detection or acquisition. Participants received notice of their freedom to withdraw from study anytime without any negative consequence. The secure data collection process supports this academic research alone based on data protection rules and ethical research procedures (Bell & Bryman, 2006).

4. Results

This section presents the empirical data derived from the analysis conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS software (Hair et al., 2019). This research employs a two-step analysis: initially, the measurement model is evaluated for reliability and validity, followed by an examination of the structural link. The tables and figures below methodically exhibit data and offer a detailed interpretation for each analytical stage's outcomes.

Table 2
Convergent Validity Test

Constructs	items	Loading	Alpha	CR	AVE
CI	CI1	0.878	0.809	0.887	0.724
	CI2	0.834			
	CI3	0.84			
DA	DA1	0.849	0.807	0.886	0.721
	DA2	0.835			
	DA3	0.864			
RS	RS1	0.842	0.855	0.902	0.698
	RS2	0.852			
	RS3	0.804			
	RS4	0.843			
RTA	RTA1	0.816	0.871	0.906	0.66
	RTA2	0.836			
	RTA3	0.81			
	RTA4	0.8			
	RTA5	0.798			
SCE	SCE1	0.794	0.934	0.944	0.627
	SCE2	0.761			
	SCE3	0.802			
	SCE4	0.786			
	SCE5	0.788			
	SCE6	0.812			
	SCE7	0.773			
	SCE8	0.783			
	SCE9	0.832			
	SCE10	0.787			
SCP	SCP1	0.764	0.804	0.864	0.56
	SCP2	0.781			
	SCP3	0.733			
	SCP4	0.736			
	SCP5	0.728			

The convergent validity assessment of all constructs in the model for factor loading, Cronbach’s alpha, composite reliability (CR) and average variance extracted (AVE) is presented in Table 2. According to Hair et al. (2019), adequate convergent validity is confirmed if the item loading is above 0.70, CR is more than 0.70, and AVE is more than 0.50. All constructs meet these criteria. We find that Cloud Integration (CI) has good internal consistency, CR = 0.887, AVE = 0.724. For DA, RS, RTA and SCP, reliability (CRs from 0.864 to 0.906) is found to be satisfactory. Supply Chain Efficiency (SCE) has the maximum item count and good reliability (CR = 0.944, α = 0.934) and acceptable AVE (0.627). SCP achieves the lowest AVE of 0.56 and is still above the threshold. When combined together these results together confirm the validity of the constructs in the convergent direction and therefore provide justify of inclusion in the structural model evaluation.

Table 3
HTMT Ratio

	CI	DA	RS	RTA	SCE	SCP
CI						
DA	0.154					
RS	0.05	0.056				
RTA	0.226	0.236	0.04			
SCE	0.577	0.647	0.059	0.664		
SCP	0.439	0.376	0.738	0.414	0.659	

In Table 3, the Heterotrait-Monotrait (HTMT) ratios are presented for assessing discriminant validity among the latent constructs. Hair et al. (2019) argue that such HTMT values below the threshold of 0.85 are acceptable discriminant validity. This condition is satisfying for all the constructs in the model. The maximum HTMT was recorded between Retal Scale (RS) and Supply Chain Performance (SCP) as 0.738 whereas the minimum HTMT was between RS and Real Time Analysis (RTA) as 0.040. The numbers are consistent with the fact that each construct is empirically distinct and not grossly correlated with others. It is found that the findings provide strong evidence for discriminant validity, which implies that the constructs underpinned the overall research model are distinct.

Table 4
Fornell Larcker

	CI	DA	RS	RTA	SCE	SCP
CI	0.851					
DA	0.126	0.849				
RS	0.033	0.013	0.835			
RTA	0.192	0.199	0.013	0.812		
SCE	0.502	0.561	0.042	0.602	0.792	
SCP	0.354	0.302	0.613	0.347	0.571	0.749

The results for the Fornell-Larcker criterion of discriminant validity are reported in Table 4. Bagozzi et al. (1981) and Hair et al. (2019) provide that discriminant validity is achieved when square roots for a construct's AVE (diagonal value) are greater than a construct's correlations with other constructs (off-diagonal values). It is easy to see that this condition is satisfied for all constructs in the model.

Table 5
Cross Loadings

	CI	DA	RS	RTA	SCE	SCP
CI1	**0.878**	0.131	0.011	0.177	0.448	0.311
CI2	**0.834**	0.056	0.036	0.147	0.41	0.291
CI3	**0.84**	0.131	0.04	0.165	0.423	0.301
DA1	0.101	**0.849**	0.034	0.171	0.479	0.259
DA2	0.092	**0.835**	0.023	0.172	0.461	0.251
DA3	0.126	**0.864**	-0.021	0.164	0.491	0.261
RS1	0.006	-0.021	**0.842**	0.019	0.03	0.52
RS2	0.023	0.008	**0.852**	0.038	0.05	0.516
RS3	0.075	-0.002	**0.804**	-0.022	0.021	0.482
RS4	0.011	0.058	**0.843**	0.005	0.038	0.529
RTA1	0.193	0.105	-0.003	**0.816**	0.506	0.271
RTA2	0.146	0.162	0.005	**0.836**	0.487	0.284
RTA3	0.194	0.218	0.03	**0.81**	0.521	0.327
RTA4	0.099	0.133	-0.011	**0.8**	0.447	0.242
RTA5	0.139	0.185	0.028	**0.798**	0.475	0.281
SCE1	0.389	0.411	0.028	**0.52**	0.794	0.472
SCE10	0.416	0.434	0.065	**0.448**	0.787	0.473
SCE2	0.378	0.439	0.012	**0.448**	0.761	0.405
SCE3	0.406	0.469	-0.024	**0.494**	0.802	0.455
SCE4	0.396	0.451	0.083	**0.448**	0.786	0.479
SCE5	0.378	0.435	0.065	**0.517**	0.788	0.475
SCE6	0.426	0.433	0.04	**0.521**	0.812	0.461
SCE7	0.403	0.448	0.058	**0.4**	0.773	0.436
SCE8	0.406	0.447	0.01	**0.475**	0.783	0.419
SCE9	0.377	0.484	-0.004	**0.484**	0.832	0.443
SCP1	0.267	0.214	0.502	0.25	**0.426**	0.764
SCP2	0.227	0.219	0.489	0.259	**0.418**	0.781
SCP3	0.3	0.253	0.43	0.265	**0.447**	0.733
SCP4	0.286	0.177	0.436	0.243	**0.408**	0.736
SCP5	0.247	0.268	0.435	0.284	**0.44**	0.728

All these inter-construct and diagonal values are greater than the corresponding inter-construct correlations. The diagonal values range from 0.749 (Supply Chain Performance) to 0.851 (Cloud Integration). The correlations of the square root of AVE for Supply Chain Efficiency (0.792) are higher than with Real Time Analysis (0.602), Data Accessibility (0.561), and Cloud Integration (0.502). Distinctiveness is also implied by retail scale (0.835), which only interacts relatively low with all other constructs. These results support the notion that all the constructs are more highly related to their respective indicators than to other constructs, indicating acceptable discriminant validity and permitting the use of these constructs in the structural model analysis.

Finally, Table 5 gives cross loadings for the further evaluation of discriminant validity. It is found that cross-loading of each item on another construct is much lower than its loading on the construct to which it belongs, thus supporting discriminant validity (Hair et al., 2019). CI items (CI1: 0.878, CI2: 0.834; CI3: 0.840) added a lot more weight to CI than to other constructs. Like DA1: 0.849, DA2: 0.835, DA3: 0.864, items located on their respective constructs have substantially much stronger loadings than their respective cross loadings and with similar items located on actual constructs. Supply Chain Efficiency items (e.g., SCE1: 0.794; SCE9: 0.832) load highest on the intended construct, while cross-loadings remain notably lower. Likewise, Supply Chain Performance items demonstrate consistent higher loadings on their designated construct (SCP1: 0.764; SCP2: 0.781), with significantly lower cross-loadings. Thus, the cross-loadings results further confirm discriminant validity, indicating each item distinctly measures its intended construct, reinforcing measurement quality.

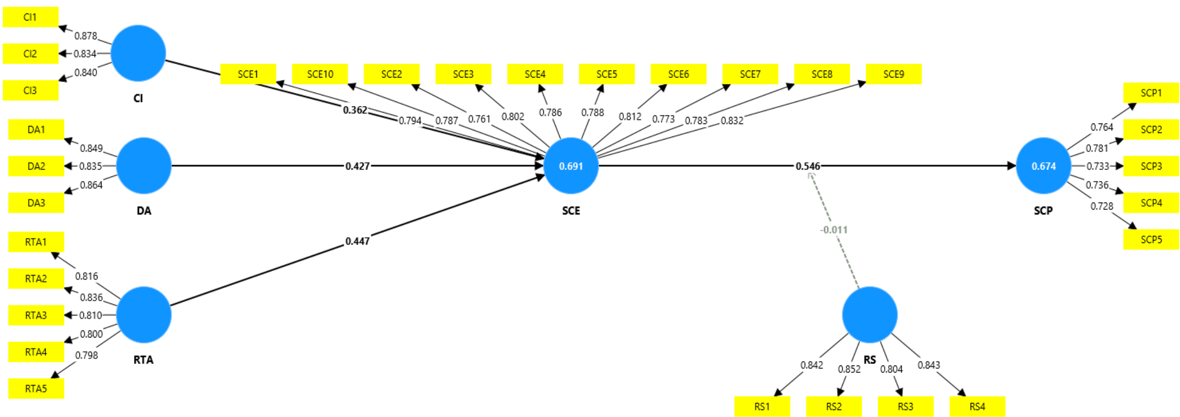

Figure 2: Measurement Model

The measurement model, as illustrated in Figure 2, shows the correlation between constructs and the indicators of the constructs. All indicators are associated with their respective latent constructs and show high loading of factors, which is in line with earlier mentioned reliability and validity tests. There are no significant cross-loadings, which indicate the discriminant validity (Hair et al., 2019). The model structure clearly demonstrates the existence of the constructs like Cloud Integration, Data Accessibility, Real-Time Analysis, Retail Scale, Supply Chain Efficiency, and Supply Chain Performance, and the measures of each construct are indicated. Tables 1-4 support the findings of reliability, convergent and discriminant validity because of the clarity and organization of the measurement model. In general, Figure 1 gives good visual assurance of accurate and integrity measurement.

Table 6

Path Analysis

	Original sample	Standard deviation	T statistics	P values
CI -> SCE	0.362	0.030	12.086	0.000
DA -> SCE	0.427	0.030	14.101	0.000
RTA -> SCE	0.447	0.032	14.108	0.000
RS -> SCP	0.589	0.029	20.542	0.000
SCE -> SCP	0.546	0.029	18.695	0.000
RS x SCE -> SCP	-0.011	0.035	0.323	0.746

Table 6 provides path coefficients, significance, and hypotheses testing results. Cloud Integration (CI → SCE: $\beta = 0.362$; $p < 0.001$), Data Accessibility (DA → SCE: $\beta = 0.427$; $p < 0.001$), and Real-Time Analysis (RTA → SCE: $\beta = 0.447$; $p < 0.001$) positively and significantly influence Supply Chain Efficiency, supporting H1, H2, and H3. Furthermore, Retail Scale significantly impacts Supply Chain Performance directly (RS → SCP: $\beta = 0.589$; $p < 0.001$), supporting H4. Supply Chain Efficiency also positively impacts Supply Chain

Performance (SCE → SCP: β = 0.546; $p < 0.001$), confirming H6. However, Retail Scale does not significantly moderate the relationship between Supply Chain Efficiency and Performance (RS × SCE → SCP: β = -0.011; p = 0.746), thus not supporting H5. The overall analysis supports five hypotheses, highlighting critical insights regarding cloud computing's role in enhancing SCM efficiency and performance. The non-significant moderation indicates uniform cloud computing benefits irrespective of firm size in the retail sector.

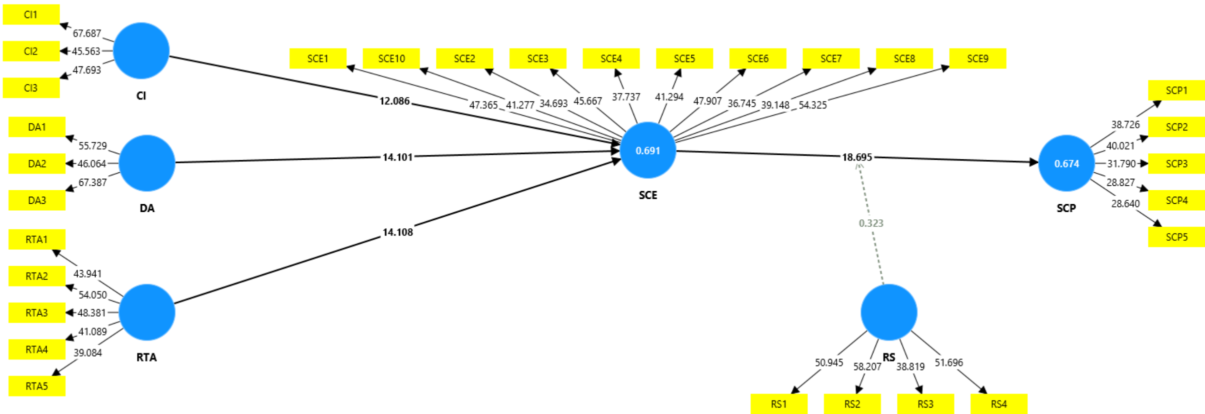

Figure 2: Structural Model

Figure 2 visually demonstrates the structural model, clearly depicting hypothesized paths among variables. Significant relationships (e.g., CI, DA, RTA → SCE; RS, SCE → SCP) align with path analysis outcomes, presenting clear and strong paths indicating predictive relevance (Hair et al., 2019).The insignificant moderation (RS × SCE → SCP) is visually noted by weak path indication, reinforcing the moderation results. The structural model illustrates the Supply Chain Efficiency's central role as a mediator, driven significantly by cloud computing factors (CI, DA, RTA). Retail Scale’s strong direct path to Supply Chain Performance further illustrates its significance. The graphical depiction effectively summarizes and validates hypothesized relationships, providing clear, visual corroboration of the statistical analysis findings.

5. Discussion

The main aim of the study was to access the contribution of cloud computing towards the improvement of the supply chain management efficiency and performance in the Chinese retail industry. The findings present substantial empirical evidence of hypothesized relationships as well as draw on various critical implications to theory and practice.

In accordance with Hypothesis 1, cloud integration positively influences the efficiency of a supply chain, which supports the previous studies (Chakraborty & Das, 2020; Gunasekaran & Ngai, 2004). In particular, the findings show that cloud computing technologies are successfully implemented in the stable supply chain processes, which increase supply chain operational efficiency, responsiveness, and resource optimization. In line with this current reality of the fact that a cloud-based platform eases communication and supports more agile supply chain operations (Boutkhoum et al., 2017; Prajapati, Mathiyazhagan, et al., 2024), this beneficial effect ensures a fluent workflow.

In such a way, the Hypothesis 2 stating that the availability of data positively influences the efficiency of the supply chain was also highly supported. This is supported by previous research by Wu et al. (2019) and Croson and Donohue (2003) who found that there is a significant change in data sharing and this change has led to a reduction in inefficiencies like the bullwhip effect, introduction of faster decision processes as well as optimum inventory control. When it comes to Gopal et al. (2022) and Sanders (2007), cloud computing will ensure that essential data related to operations is accessibly available to the manager at a timely moment to make more effective managerial decisions and be responsive to the demands of consumers and the overall supply chain agility.

Based on the support of Hypothesis 3, it might be insinuated that real-time analytics are highly essential in providing high-quality supply chain efficiencies. This observation aligns with other studies that suggest that analytics should be timely as it provides a business with an edge in a rapidly evolving market (Holloway, 2024; Shang et al., 2010). The ability to perform real-time analytics by enabling quick analysis and decision-making of the available information, lessen the uncertainty and enhance the operational responsiveness of the retail supply chains (Kudirat Bukola et al., 2024; Muthukalyani, 2024).

Our finding for Hypothesis 4, regarding the direct effect of retail scale (firm size) on the supply chain performance, was clear. The presence of a large firm is a perfect justification in older literature about reasons why larger firms are often more effective at outperforming smaller ones based on their possession of greater resources, economies of scale, as well as more advanced technological capabilities (Lee, 2019; Roespinoedji et al., 2019). Therefore, the use of the size advantage of larger retailers in the Chinese market helps them to compete and perform better in English, translating into better operational outcomes and higher competitive market conditions (Kot et al., 2018; Wiengarten et al., 2012).

Hypothesis 6 was robustly supported, in line with the essential nature of supply chain efficiency in favoring improved supply chain performance (Bruque-Cámara et al., 2016; Zelbst et al., 2012). Efficiency improvement results directly in lower operating costs, increased responsiveness, better stock management and improved customer satisfaction, a phenomenon that is generally in line with Abdallah et al. (2014) and Brandenburg et al. (2019). In addition, these outcomes demonstrate clear improvements with respect to efficiency as a key strategic objective in China's dynamic retail market.

Hypotheses Hypothesis 5 (retail scale moderates the relationship between supply chain efficiency and performance) was the only hypothesis that was not supported. This contrasts with the expectations in the past according to the previous literature (Arunachalam et al., 2018; Zhou et al., 2023). This may be attributed to the fact that cloud computing provides universal good to Bitcoin to all firms regardless of the scale in terms of competition. This non-significant moderation indicates that scale is not important in relation to the extent to which the cloud solutions can assist retail business in general and application-intensive Chinese market, where such technology innovation is a norm. What this finding suggests is that the cloud might be a leveler, which is the small firms will be able to take advantage of sources of advantage that were previously available solely to the larger firms.

Overall, the results of the current research make important contributions to current knowledge by confirming the importance of critical roles of cloud integration, data accessibility, real-time analytics, and the retail scale to increase the efficiency and performance of the supply chain. They affirm that cloud computing is an important strategic tool in modern supply chain management of retail business and offer broad empirical evidence in the environment of the Chinese retail industry.

6. Conclusion, Implications, Limitations, and Future Research

This paper has explored how cloud computing can enhance efficiency and performance of the supply chain management of the Chinese retail industry. Lastly, the empirical results were quite robust in justifying the advantage of cloud integration, the availability of data and real-time analysis on the efficiency of the supply chain, which enhances the performance of the supply chain. We discovered that direct significant predictors of improved performance are retail scale and not their moderating role as hypothesized between efficiency and performance. The results, collectively, also confirm the transformative power of cloud computing in retail supply chain business, irrespective of the scale of the company, which is centralized to the present-day service practice of the retail business in China in a dynamic and evolving manner.

The study has practical implications on retail practitioners and policymakers. In order to maximize the advantages of cloud computing to the retail business in China, it is worth considering how to position the significance of the new technology strategically in terms of increasing the availability of information and the introduction of real-time analytics as the means to pursue better rates of operational efficiency and competitive advantage. The managers of all the various magnitudes of the retail scale could use cloud solutions to achieve significant performance enhancement, and, thus, propose strategic investment in the cloud technologies could be universally helpful in the field. Policymakers can also use these findings to develop enabling structures and incentives to ensure more cloud computing technologies become adopted in line with Made in China 2025 policies that provide the national policy of digital transformation.

As much as such insights are very valuable, there are certain limitations that must be mentioned. The study is cross-sectional hence cannot be causal, and the findings are mainly how the managers feel at a certain time. Moreover, the results of research based on discussing only managers of the Chinese retail sector may not be extrapolated to other areas or sectors. Moreover, the paper used self-report questionnaires, and this may introduce response biases; it was attempted to eliminate the biases by the validation of the measurement scales and by assuring anonymity.

More longitudinal designs can be used to capture the dynamic effects of cloud computing on the management of the supply chain that might change with time. Other contextual variables like regulatory environments, level of competition and maturity of technology may be other areas that can be studied in later research in order to understand better. Other measures to improve extrapolation of the findings and to be able to emphasize the context-specific dynamics involve using cross-domain and cross-cultural comparative studies. Further in-depth qualitative research of managerial nature may bring out a deeper insight into barriers in implementation and strategic factors that enable adoption of cloud computing.

Author Contributions

Muhammad Ashfaq: contributed to conceptualization, methodology, data analysis, and original manuscript writing
Rashid Sultan: contributed to literature review, data collection support, interpretation of results, and manuscript revision.

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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