

# Sustainable Supply Chain Management, Information Technology, and Firm Performance: The Mediating Power of Agility and Supply Chain Integration

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**Abstract:** This study investigates how sustainable supply chain management (SCM) practices and information technology (IT) drive firm performance in small and medium enterprises (SMEs), with a focus on the mediating roles of supply chain agility (SCA) and sustainable supply chain integration (SSCI). Drawing on data from 219 managers and supply chain experts in Iranian SMEs, structural equation modeling (SEM) revealed that both sustainable SCM practices and IT adoption significantly enhance firm performance directly and indirectly through SCA and SSCI. Sustainable SCM practices demonstrated a robust influence on SSCI ( $\beta = 0.35, p < 0.001$ ), SCA ( $\beta = 0.49, p < 0.001$ ), and firm performance ( $\beta = 0.44, p < 0.001$ ), while IT similarly impacted SSCI ( $\beta = 0.34, p < 0.001$ ), SCA ( $\beta = 0.39, p < 0.001$ ), and performance ( $\beta = 0.21, p < 0.001$ ). Critically, SCA and SSCI emerged as pivotal mediators, explaining 48% of the variance in firm performance. The findings underscore that agility and integration transform sustainable and technological investments into competitive outcomes, enabling SMEs to navigate dynamic markets. Practical insights highlight the need for firms to prioritize cross-departmental coordination, IT-driven customer insights, and adaptive decision-making frameworks.

**Keywords:** firm performance; information technology; supply chain agility; supply chain integration; supply chain management; sustainable

## 1 INTRODUCTION

The concept of a firm's performance is quite extensive, including not only the results produced by the organization but also various other factors that contribute to its overall effectiveness. Alternatively, a firm's performance refers to its ability to accomplish its mission and activities and to achieve its objectives [1]. In competitive markets, organizational leadership consistently prioritizes performance enhancement as a strategic necessity. This imperative stems from the understanding that sustained operational refinement is vital for maintaining relevance—not merely to survive but to thrive amid shifting industry demands and rival market forces. Therefore, Adapting and implementing effective strategies and continuously improving performance is vital for companies in today's changing, complex, and uncertain competitive environment). Factors such as accelerated environmental shifts, fiscal constraints, organizational streamlining processes, and heightened public demands for more accountability of organizations for their performance, a greater emphasis has been placed on performance management as a result. Due to various factors including swift changes in the environment, budget shortfalls, organizational downsizing and restructuring, as well as increasing societal demands for accountability in performance, there has been a heightened focus on performance management. In other words, one of the main topics in the organizational analysis is performance and there is a constant search for ways to improve the performance of companies [2]. Therefore, the central goal of this paper is to explore the influence that sustainable SCM practices and information technology (IT) may have on performance of firm by taking into account the mediation role that agility and sustainable supply chain integration (SSCI) may play in determining firm performance.

SCM integrates supply chain activities to continuously achieve competitive advantage as well as their information

by improving chain relationships. Therefore, SCM is a process that integrates supply chain activities and related information currents by improving and coordinating activities in a chain of production and supply. Adding sustainability to SCM has expanded its concept [3]. Sustainability is defined as a process by which a balance is maintained between meeting current needs and meeting future generations' needs. A sustainable SCM manages material, information, and capital flow and coordinates organisations as part of the supply chain, and integrates underlying principles of sustainable development that relate to the economy, the environment, and society, resulting from the needs of customers and beneficiaries [4]. To ensure long-term viability in supply chain operations, participants in sustainable supply chains must balance dual imperatives: adherence to rigorous social and environmental standards, and the preservation of economic competitiveness. This necessitates aligning with consumer expectations while fulfilling key economic benchmarks to sustain market relevance [5].

Sustainable SCM has emerged as a new and important approach by using environmental risk reduction to gain market share and profit. Organizations that intend to implement sustainable SCM need to review different strategies to reduce energy costs [6]. A sustainable SCM controls environmental effects in its product life cycle by emphasizing the integration of environmental management and SCM coordinates supply chain members, and encourages information sharing between them [7]. The performance of firms can be significantly impacted by sustainable SCM, according to studies [8].

Currently, IT is an incentive for the globalization of products and markets, and it increases the dynamics of services and monetary-financial currents, and often allows the increasing performance and efficiency [9]. A glance at the developed countries reveals that IT has played a vital role in their comprehensive development. Comprehensive

information and IT used at the right time prevents resource waste and unnecessary and unimportant tasks and most importantly, ineffective and inefficient decisions. In addition, technology is one of the most valuable resources of organizational processes to improve growth and productivity. Therefore, Improved performance through better allocation of technology resources has emerged as a significant subject in contemporary research literature. Overall, a significant amount of literature has been written on the importance of IT-related skills, competencies, and capabilities due to the important role they play in the performance of companies. Evidence suggests that IT has a positive influence on firm performance [10]. IT adoption not only optimizes operational efficiency but also supports customer-centric strategies, such as participatory digital marketing models facilitated by knowledge management [24, 25], which can further amplify supply chain responsiveness.

A supply chain's agility (SCA) is becoming increasingly important in response to short-term changes in the supply chain as a result of these changes; in fact, agility means that in order to adapt quickly, the supply chain has to be flexible to changes and can respond appropriately to them [11]. In other words, agility enables the supply chain to face unexpected changes. Companies realize that they need agility to survive and remain competitive. In addition, not every company has available resources to deal with different opportunities. Therefore, global competition requires organizations to Provide support to suppliers and customers by aligning their operations to achieve higher agility than other organizations; this integration is called "agile supply chain" [12]. SCA promotes the adaptability and flexibility of businesses and enables them to respond to market changes quickly and effectively. As a winning strategy, advocates of SCA recommend businesses use it as their supply model to compete at national and international levels [13]. Results of the conducted research have also shown that the performance of firms is positively affected by SCA [14, 15].

By integrating the supply chain process, all barriers tend to be removed in order to enable the smooth flow of materials, resources, and information throughout the supply chain. In order to reduce ambiguity in terms of integration, sharing information contributes to improving the capability to predict and reduce costs [16]. Supply chain integration (SCI) emphasizes high levels of customer-supplier engagement to reduce product development costs through the involvement of primary suppliers [17]. Results of the conducted studies have also shown that an important factor in a firm's performance can be attributed to SCI [18].

Theoretical research consistently underscores the significant impact of Sustainable SCM practices, IT adoption, operational agility, and SSCI on organizational performance. However, empirical studies reveal a critical gap: limited evidence has established a comprehensive framework linking sustainable SCM practices and IT capabilities to performance outcomes, particularly through the mediating effects of agility and SSCI. To bridge this gap, constructing a holistic model is imperative. Such a framework would elucidate the pathways through which IT

investments enhance firm performance, with agility and SSCI serving as pivotal intermediaries in this relationship.

## 2 CONCEPTUAL MODEL

A conceptual framework (Fig. 1) was derived through an analysis of existing literature. This model positions Sustainable SCM practices and IT as independent variables, while SCA and SSCI function as mediating factors. Firm performance is established as the dependent variable, capturing the cumulative impact of these interrelated components. Therefore, these hypotheses are presented in the following order:

- H1: Sustainable SCM practices are effective on SSCI.
- H2: Sustainable SCM practices are effective on SCA.
- H3: Sustainable SCM practices are effective on firm performance.
- H4: IT is effective on SSCI.
- H5: IT is effective on SCA.
- H6: IT is effective on firm performance.
- H7: SSCI is effective on SCA.
- H8: SSCI is effective on firm performance.
- H9: SCA is effective on firm performance.
- H10: SSCI and SCA mediate the influence of sustainable SCM practices on firm performance.
- H11: SSCI and SCA mediate the influence of IT on firm performance.
- H12: The effect of SSCI on firm performance is mediated by SCA.

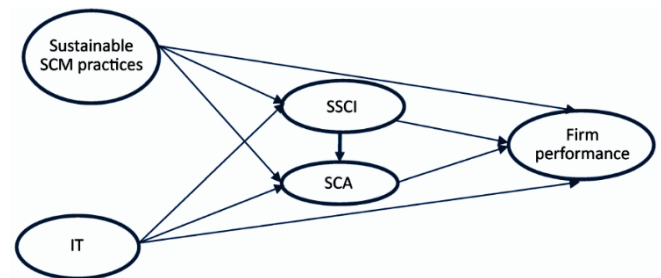


Figure 1 The conceptual model

## 3 RESEARCH METHODOLOGY

This study employed a descriptive correlational design combined with structural equation modeling (SEM) to analyze the hypothesized relationships between variables. SEM was selected for its capacity to evaluate complex, multivariate dependencies within the proposed framework [20, 21, 27].

### 3.1 Population and Sample

The target population comprised managerial personnel, deputies, and supply chain specialists within small-to-medium enterprises (SMEs) operating in Iran. A total of 250 survey questionnaires were distributed to eligible participants in these roles. After excluding incomplete responses, 219 valid questionnaires were retained for analysis. Responses were collected using a five-point Likert

scale, with anchors ranging from 1 ("strongly disagree") to 5 ("strongly agree").

### 3.2 Instruments

**Sustainable SCM practices:** Sustainable SCM practices were evaluated using a validated instrument adapted from Hong et al. [8]. The tool comprises 16 items grouped into five dimensions: trust and coordination within the supply chain (3 items), collaborative learning across supply chain partners (3 items), strategic orientation of supply chain operations (3 items), proactive risk management in supply networks (4 items), and continuity planning for supply chain resilience (3 items).

**IT:** Jiang and McCabe's [19] questionnaire was used to measure IT in 6 items; 3 items measure technology usage for exploitation and 3 items measure technology usage for exploration.

**SCA:** In a questionnaire developed by Gligor and Holcomb [14], nine items were used to measure SCA.

**SSCI:** Shashi et al.'s [17] questionnaire was used to measure SSCI. This questionnaire consists of 8 items; 4 items measure internal integration and 4 items measure external integration.

**Firm performance:** To measure firm performance, the questionnaire developed by Alipour et al. [22] was used. This questionnaire consists of 5 items.

## 4 RESULTS

Descriptive statistics for the variables—including mean, standard deviation, skewness, and kurtosis—are summarized in Tab. 1. A key assumption in causal modeling is multivariate normality, which requires absolute skewness values below 3 and kurtosis values under 10.

**Table 1** Descriptive indices of variables

Variable	Mean	SD	Skewness	Kurtosis
Sustainable SCM	3.92	0.96	0.664	-0.617
IT	3.96	0.89	0.763	0.562
SSCI	3.81	0.85	0.594	-0.652
SCA	3.64	0.91	0.737	0.864
Firm performance	3.97	0.74	0.709	-0.671

All variables in Tab. 1 exhibit skewness and kurtosis below one. Therefore, causal modeling is normal. The matrix of correlation of variables is presented in Tab. 2.

**Table 2** Correlation matrix

Variable	Sustainable SCM	IT	SSCI	SCA	Firm performance
Sustainable SCM	1				
IT	0.61**	1			
SSCI	0.51**	0.49**	1		
SCA	0.63**	0.53**	0.47**	1	
Firm performance	0.59**	0.41**	0.44**	0.56**	1

\*\* $p < 0.01$

The data presented in Tab. 2 indicate a statistically significant correlation between the variables ( $p < 0.01$ ). In

Fig. 2, the tested model for the hypotheses is shown along with the standardized values on each path. SSCI, SCA, and firm performance are positively influenced by sustainable SCM practices.

Integrated supply chains, SCA, and firm performance are positively impacted by IT. SCA and firm performance are positively affected by SSCI. Agility in the supply chain improves the performance of firms in a significant way.

Tab. 3 reports the direct effects, t-values, and significance levels of the variables.

**Table 3** Results related to direct effects

Path	$\beta$	t-value	Sig.	Variance explained
On firm performance via:				0.48
SCA	0.30**	3.237	0.001	
SSCI	0.26**	3.012	0.001	
IT	0.21**	2.784	0.001	
Sustainable SCM practices	0.44**	4.650	0.001	
On SCA via:				0.55
SSCI	0.33**	4.638	0.001	
IT	0.39**	5.041	0.001	
Sustainable SCM practices	0.49**	6.930	0.001	
On SSCI via:				0.24
IT	0.34**	4.046	0.001	
Sustainable SCM practices	0.35**	4.253	0.001	

The analysis reveals that sustainable SCM practices demonstrate significant positive associations with SSCI, SCA, and firm performance, as evidenced by the data in Tab. 3. Furthermore, IT capabilities positively influence integrated supply chain operations, SCA, and overall organizational performance. A direct positive correlation exists between SSCI and firm performance outcomes, while SCA significantly enhances firm performance metrics. The proposed model accounts for 48% of the variance in firm performance, 55% in supply chain agility, and 24% in SSCI, as detailed in Tab. 3. Another feature of SEM is to test the indirect influences of variables on each other. As shown in Tab. 4, indirect effects have been evaluated.

**Table 4** Results of the indirect effect of the tested model

Path	$\beta$	t-value	Sig.
Mediating role of SSCI in the effect of: SCM practices on firm performance	0.09**	2.458	0.05
SCM practices on SCA	0.12**	3.135	0.01
IT on firm performance	0.09**	2.416	0.05
IT on SCA	0.11**	3.049	0.01
Mediating role of SCA in the effect of: SCM practices on firm performance	0.15**	2.933	0.01
IT on firm performance	0.12**	2.724	0.01
SSCI on firm performance	0.10**	2.654	0.01

The analysis in Tab. 4 reveals that SSCI serves as a significant positive mediator in four critical relationships: (1) between sustainable SCM practices and firm performance, (2) between sustainable SCM practices and SCA, (3) between IT adoption and firm performance, and (4) between IT adoption and SCA. Furthermore, the study confirms that SCA itself mediates the positive influence of IT, SSCI, and sustainable SCM on firm performance.

Goodness of fit indices of model are  $GFI = 0.94$ ,  $AGFI = 0.92$ ,  $SRNR = 0.041$ ,  $\chi^2/df = 1.63$ ,  $PNFI = 0.73$ , and  $RMSEA = 0.054$ . The results show that the obtained fit indices are all

adequate and the data has a good fit with the factor structure of this model. This methodological rigor aligns with contemporary standards for psychometric validation, as

exemplified in cross-cultural adaptations of performance measurement tools by Laybidi et al. [30].

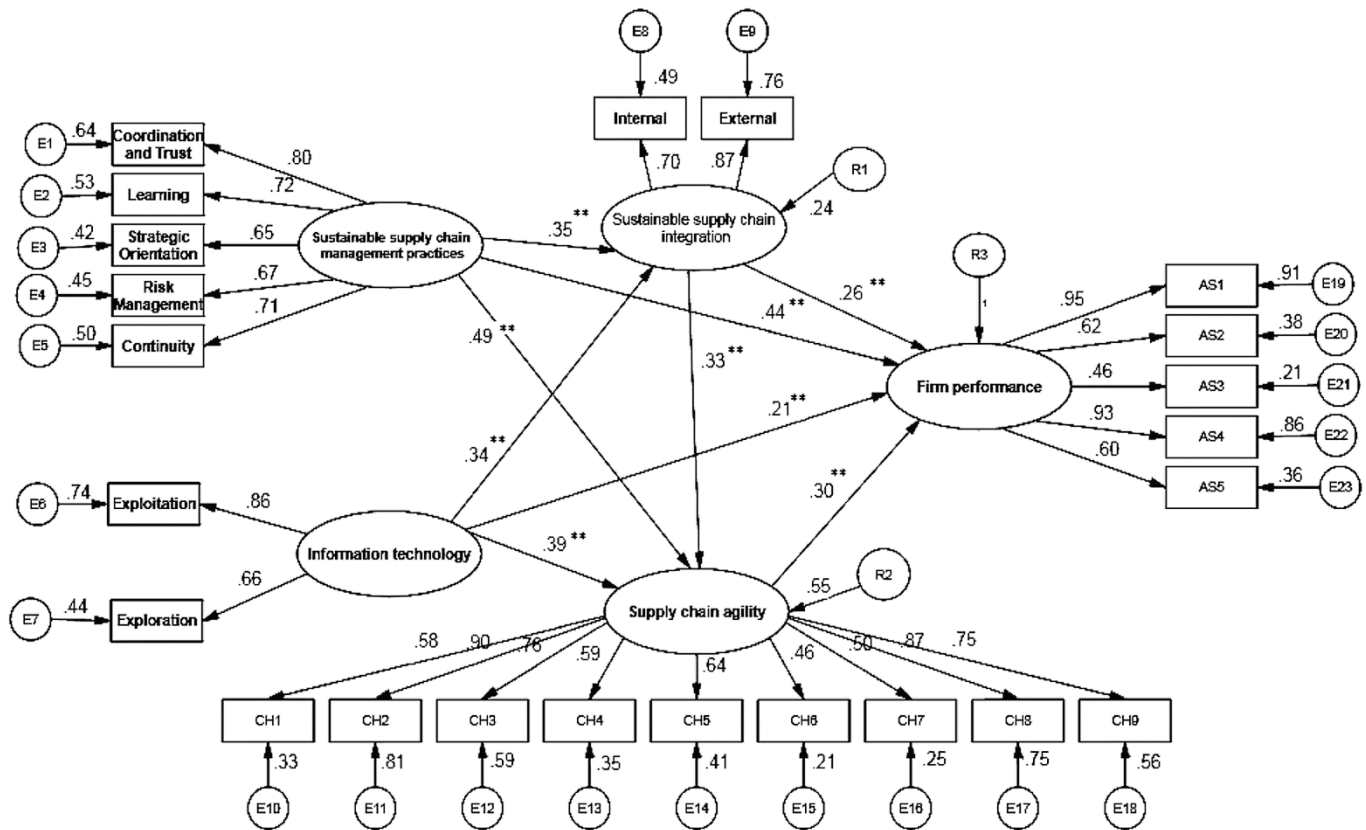


Figure 2 The tested model

## 5 DISCUSSION

The study considered the mediating role of agility and SSCI when modeling the influence of sustainable SCM practices and IT on firm performance. Based on the study's results demonstrated, data fit is quite good for the proposed model. It is quite capable of explaining 48% of its variance in firm performance, 55% of it is variance in SCA, and 24% of it is variance in SSCI. In this study, the results revealed that sustainable supply chain management practices can positively affect SSCI, SCA, and firm performance in a significant manner. This finding is consistent with Hong et al. [8]. To explain this finding, SSCI and SCA will increase and ultimately firm performance will improve if the firm uses sustainable procurement methods in its supply chain process, considers its sustainability in the design of its products, uses sustainable marketing methods, evaluates the life cycle of its products, has environmental and sustainability approvals, considers purchase of the required raw materials, considers their sustainability, provides environment-related training programs for employees and suppliers, organizes environmental education activities for employees and suppliers, promotes the participation of employees and suppliers for sustainable development, and introduces environmental issues to customers and suppliers.

The impact of IT on the sustainability of supply chains, the agility of supply chains, and the performance of firms is significant and positive. This finding is consistent with Slim et al. [10]. Advanced IT infrastructures, including evolutionary data mining systems for spam detection [37], further enhance supply chain transparency by safeguarding data integrity and improving real-time decision-making efficiency. To explain this finding, SSCI and SCA will increase and ultimately firm performance will improve if the firm processes orders, issues invoices and settles with customers and provides support based on IT; information about shipping and delivery is exchanged through IT-based support with the company's primary customers, and stock and inventory information is managed through IT-based support, uses IT to understand the sales process and preferences of its primary customers, uses IT for integration of the firm and its primary customers, creates new business uses opportunities by using IT to apply firm capabilities and customer expertise, is aware of recent advancements in sciences and technologies, is able to create advanced technology processes, is able to absorb new technologies and useful innovations, has skilled tech employees in hardware and operating system, is able to master, produce or absorb key and essential commercial technology and is effective in launching programs for internal technology development or capabilities for absorbing technology from R&D centers or from suppliers and customers. The findings align with

research on CRM systems in online retailing, where IT-enabled customer engagement directly strengthens supply chain coordination and market adaptability [26]. This mirrors findings by Latifi et al. [27], where system quality in VR environments critically enhanced user engagement. Similarly, emerging IT innovations like FinTech adoption [31] and secure network infrastructures [32] demonstrate the expansive role of technology in enhancing operational efficiency across sectors. Advanced computational tools, such as the African Vulture Optimizer for reorder decision-making [28], further demonstrate how algorithmic innovations can optimize supply chain agility and operational efficiency. Emerging methodologies in big data partitioning [35] and IoT security frameworks [36] further demonstrate how advanced IT infrastructures can enhance supply chain transparency and resilience.

Integrated supply chains lead to improved SCA and performance for firms. This finding is consistent with Liu et al. [18]. According to this finding, SCA will increase and ultimately firm performance will improve if the firm is able to coordinate different teams of the organization in supply chain process, is able to coordinate tasks in different departments throughout the supply chain process, provide timely information among different departments and teams of the organization in the supply chain process, assist suppliers during the supply chain process by getting their cooperation and support, provide timely information to suppliers, is able to adapt its services to environmental changes, has adequate knowledge about characteristics of the supply chain partners, in addition to participating in SSCI, the firm's competitive position improves through interaction with supply chain partners, and supply chain partners contribute to the achievement of common goals, there is good investment in development of relationships between supply chain partners, supply chain partners use the same value system and additional efforts are made to improve relationships in the supply chain.

SCA exerts a significant positive influence on firm performance, a finding corroborated by prior research [14, 15]. This relationship can be attributed to a firm's capacity to (1) rapidly detect shifts in market dynamics, (2) identify emerging opportunities and threats, (3) streamline bidirectional information flows with suppliers and customers, (4) execute timely, data-driven decisions to mitigate risks or capitalize on opportunities, and (5) adapt operational processes—such as order specifications—to align with evolving customer demands and market conditions. Collectively, these agile capabilities enhance organizational responsiveness, driving measurable improvements in performance outcomes.

## 6 CONCLUSION

The findings demonstrate that SCA and SSCI act as strong mediating mechanisms, amplifying the positive effects of sustainable SCM practices on firm performance. Similarly, both agility and SSCI play critical roles in transmitting the influence of IT on organizational outcomes, with statistically significant interdependencies observed between these mediators. Notably, SCA further facilitates the relationship between SSCI and firm performance,

underscoring its centrality in driving competitive advantage. These results collectively affirm that sustainable SCM practices enhance performance metrics primarily by fostering agility and integration within supply networks.

This research is constrained by its reliance on self-reported data and a sample restricted to managers, assistants, and supply chain professionals within Iranian SMEs, limiting the generalizability of conclusions. Future studies could address these gaps by employing qualitative or mixed-method approaches to explore the nuanced dynamics of sustainable SCM practices, particularly in diverse geographic and organizational contexts. Future studies could also employ nonparametric causal inference frameworks like Bayesian Additive Regression Trees (BART) to address potential nonlinear dynamics in supply chain relationships, particularly when observational data introduces unobserved heterogeneity [33, 34]. Future studies could also adopt integrated multi-criteria decision-making frameworks, such as those applied in water resource management [38], to evaluate trade-offs between environmental sustainability and operational efficiency in supply chain strategies. Additionally, triangulating self-report data with objective performance metrics (e.g., operational efficiency ratios, financial records) could strengthen the validity of findings. Future studies should adopt mixed-method approaches, combining self-reported data with spatial analyses like Social Network Analysis (SNA) to map how regional industrial clusters [23] influence supply chain resilience. Automated formative assessment tools [29] could further evaluate and enhance participant comprehension during data collection, addressing potential biases in self-reported measures. Furthermore, given evidence that monetary policy uncertainties asymmetrically influence financial market stability [39], future investigations should examine how macroeconomic policy shifts interact with supply chain agility and integration to shape firm resilience.

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