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IMPACT OF INTERNET OF THINGS ON SUSTAINABLE SUPPLY CHAIN PERFORMANCE: THE EMPIRICAL PARALLEL MEDIATION MODELS

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ABSTRACT

Manufacturing companies in this era struggle to develop an integration mechanism for sustainability in the Pakistan context. Manufacturing firm performance highly depends upon integrating a digital supply chain to gain competitive advantages. Therefore, this present study shows the influence of the internet of things on sustainable supply chain performance in manufacturing organizations in Pakistan. Furthermore, The mediating roles of digital supply chain integration and competitive advantage between sustainable performance and internet of things. This study sample data is based on 369 respondents from manufacturing organizations in Pakistan. The study results showed that the Internet positively influences sustainable performance in manufacturing organizations in Pakistan. Furthermore, there are partial mediating roles of median digital integration and competitive advantage between the internet of things and sustainability. This study helps regulators and policymakers use the latest technologies for business growth.

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INTRODUCTION

Modern companies seek innovative technology breakthroughs to address the complicated consumer needs increasingly recognized for sustainable business performance (Fatorachian & Kazemi, 2021). The latest technology deploys automation technologies in numerous industrial sectors, primarily supporting technology like IoT latest devices and cyber-physical systems (Sreedharan & Persis, 2019). The latest technology, industry 4.0, demands efficient integration between people, machines, goods, and customers to boost corporate competitiveness by lowering production costs, shortening lead times, and improving product quality (Tiwari, S. 2021). Digitalization links with supply chain boost and increase data

collection, analysis, and efficient decision-making, which may improve workflows and adaptability (Kittipanya-Ngam & Tan, 2020). Digitalization has increased supply chain and organization performance as well. Furthermore, this may help create intelligence and increase integrated supply chain systems for communication (Fatorachian & Kazemi, 2021). Real-time information-sharing across departments using various latest technologies can improve supply chain performance (Ghadge et al., 2020). Digitalized firms develop, improve service, gain competitive value, adapt to market changes, and minimize costs (Lee et al., 2022). Digital system helps managers to identify better decisions and maximize profit (Dey & Seok 2024). The latest technology has changed supply chain system (Boehmer et al., 2020). Using these technologies, the company may improve efficiency, effectiveness, and sustainability (Fatorachian & Kazemi, 2021). These technologies may enhance sustainable performance through increasing integration capabilities (De Vass, Shee & Miah 2018). Thus, logistics operations must incorporate the Internet of Things to be productive and efficient. These cutting-edge technological breakthroughs influence enterprises, increasing supply chain and organization performance systems (Tiwari, S, 2021). Digital integration supply chain systems are vital for business performance because they efficiently transfer information and create smooth organizational procedures. It incorporates information exchange, cooperation, and agility to save costs, enhance service, and simplify decision-making within internal and external departments (Boon-itt & Wong, 2011). The Internet of Things impacts digital integration by influencing many operations, vendors, and consumer satisfaction. This competes for market share, creating different options for suppliers and customers (Khan et al., 2020)—the implemented IoT solutions to make significant progress in different industries. Through IoT adoption, organizations have gained productivity, safety, security, cost reduction, and service to customers. Internet of Things deployment benefited sustainable performance (Hofmann et al., 2015). digitization relies on the IoT's intelligent goods and services (De Vass, Shee, & Miah 2021). IoT solutions streamline processes, reduce product discontinuance risk, and boost competitiveness (Lee et al., 2022). It progresses procedures, reduces costs, and maximizes profit (Haddud et al., 2017). Supply Chain partner involvement and integration may also improve company sustainability by exchanging accurate and timely information (De Vass, Shee, & Miah 2021). However, technical and social constraints delay IoT implementation. Understanding IoT possibilities and challenges improves efficiency and outputs (Lee et al., 2022). Therefore, study investigates benefit internet of things on digital supply chain integration, competitive advantages, and sustainable supply chain. This research supports theory resource-based view, this research examined how firm resources on the internet of things enhance digital integration to improve sustainability. Thus, this work's main originality and contribution is identifying and measuring how IoT deployment improves supply chain efficiency. This present study shows the influence of internet of things on sustainable performance in manufacturing organizations in Pakistan. Furthermore, The mediating roles of digital integration and competitive advantage between sustainable performance and internet of things. We will provide findings and advice for managers regarding the benefits and implications of these in industries.

LITERATURE REVIEW

Theories Implication

According to the Resource-based approach, company assets, capabilities, processes, information, and knowledge provide competitive advantages and excellent organizational performance (Barney, 1991). This approach examines innovations for sustainability (Tukamuhabwa et al., 2023)—the capacity of the firm to produce new competitive products (Teece et al., 1997). It is for efficient management, information exchange, relationship management, technology transfer, and emerging technologies (Singh et al., 2019). The resource-based perspective theory explains and predicts how a corporation might use it to gain advantages. Furthermore, the dynamic capabilities theory approach states that digital SC integration skills are essential to organizational success (Salah et al., 2023). This research also uses organizational capacity theory. As resource-based theory shows, companies can improve their performance (DeVass et al., 2018). Internet adoption may increase a firm's ICT skills (Verona, G. 1999). Digital integration increases firm performance (DeVass et al., 2018). Integration also helps grow communication networks (Verona, G. 1999).

Internet of Things and Sustainable Supply Chain Performance

Supply chain management with digitalization involves integrating to improve sustainability (Hennelly et al., 2022). As technology becomes more critical, companies should modernize their processes to be more integrated. Therefore, the firm invested in the latest technologies to increase revenue and business value (Buyuokzkan & Gofe, 2018). Effective digital platforms like the Internet of Things provide procedures and collaborative activities, known as capabilities, to enhance output (Dutta et al., 2020). These attributes may be nurtured the success (Surucu-Balci & Balci, 2024). Digital transformation involves several technologies help to increase the performance (Surucu-Balci et al., 2024). IoT will allow SCs to reveal container and item locations for a better traceability platform (Irannezhad & Faroqi, 2023). The latest technology adoption increases the performance results. Moreover, data communication procedures would allow these items to communicate information independently across the Internet (Pal, K. 2023). Supply chain management with IoT adoption improves efficiency and visibility and challenges trust and organizational change. Supply chain visibility tracks products from manufacture to consumption, whereas supply chain efficiency uses resources efficiently to satisfy customer service requirements at low cost (Pettersson, A. 2008). Thus, supply chains need digital systems to track freight, payments, and other data to obtain competitive advantages (Taj et al., 2023). Now, many organizations use Internet of Things implementation for better performance (Lee et al., 2022). New technology integration into corporate contexts, structures, and models is the most challenging part (Haddud et al., 2017). IoT technology is used for adoption for better performance (Narwane et al., 2022). As per discussion, the hypothesis is proposed: Hypothesis H1: The insignificant influence on sustainable supply chain performance.

Mediating Role of Competitive Advantages

Traditional systems flaws become apparent when supply chain management advances (Liu & Zheng, 2022). Internet of Things integration may deliver an edge over competitors (De Vass et al., 2021). Supply chain

partners must integrate more to meet changing customer expectations and competitive conditions. Integrated supply networks have greater efficiency (Ozdemir & Aslan, 2011). Due to its difficulty reproducing, supply chain integration may provide firms with a competitive edge and operational benefits (Koc et al., 2022). Supply chain integration boosts competitiveness in Indonesian manufacturing (Sinaga et al., 2019). digitalization has improved digital integration, giving it advantage for growth (Setiawan et al., 2023). Improving performance is essential for new competitive advantages. Effective supply chain performance strategies depend on an organization's performance practices (Adebayo, 2012). Procedures are needed to establish competitiveness, which boosts firm performance. Interactions with supply chain partners frequently affect an organization's performance. Integration improves business performance (Abdel-Basset et al., 2018). Digital technology integration is improving competitiveness (Haseeb et al., 2019). Digital technologies partially mediate the competitive advantage for organization performance (Koç et al., 2022). Supply chain techniques, including information sharing, may improve operational effectiveness (Li et al., 2009). Performance may improve through technologies and reduce costs (Choudhury et al., 2004). Technology and automotive with digital integration improve sustainability (Boubker, 2022). As per discussion, the hypothesis is suggested: Hypothesis H2: There is a positive relation among the internet of Things and competitive advantages. Hypothesis H3: There are positive relationship occurs between competitive advantage and sustainable performance. Hypothesis H4: A partial mediation association of competitive advantage exists among and sustainable performance and internet of things.

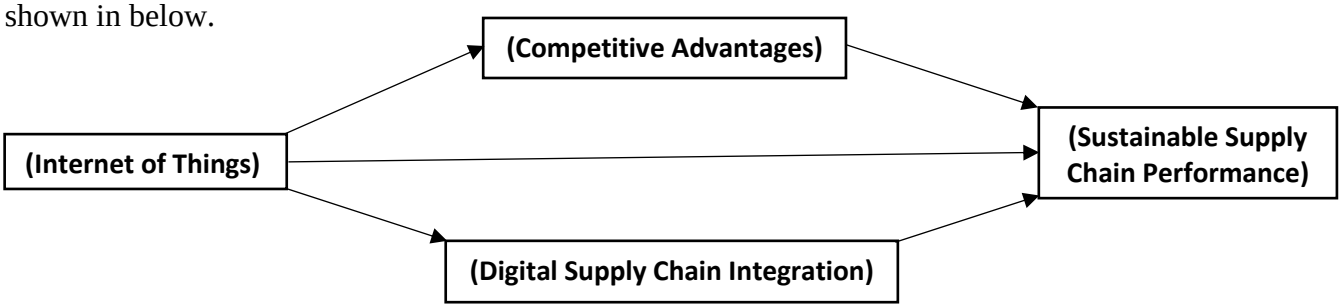
Mediating Role of Digital Supply Chain Integration

A company works with its suppliers to improve its operations (Tiwari, S. 2021). Digital integration increases resource output and knowledge and reduces costs (Wang et al., 2016). The latest technologies have boosted revenue and business value (Buyukozkan & Goçer, 2018). Companies must integrate digitally to organize and satisfy consumer wants and expectations (Liu & Chiu, 2021). Production, sales, and material management have added value to performance (Abdullah et al., 2021). IoT is increase the operations (Abdel et la, 2018). Internet of things promotes the integration of organizations (DeVass & Miah, 2018). The Internet of Things improves transparency, resilience, and valuable service (Abdullah et al., 2021). Digital integration may considerably affect the supply chain (Huo, B. 2012; Zhao et al., 2013). Improved information interchange with the IoT may promote cooperative planning, forecasting, and cooperation, integrating supply chains. As a critical instrument for company integration, the IoT has shaped the digital industrial age, potentially improving operational efficiency (Karim et al., 2022). Supply chain management benefits from decision automation, RFID integration, wireless sensor networks, and mobile applications (Lee et al., 2022). Performance is improved over digital technologies (Hennelly et al., 2020). IoT-enabled digital integration improves productivity and customer loyalty. Digital integration measures competitiveness because business managers integrate all operations (Zhao et al., 2013; Siagian et al., 2021). Integrated processes, trained people, and better supplier-customer connections may improve supply chains, save costs, and improve quality. Digital supply chain integration boosts performance

(Siagian et al., 2021; Yu, W, 2015). Digital technologies with digital integration enhance sustainability (Kamble et al., 2023). Digital integration, sustainability, integration mediation with digitalization and organization performance (Oubrahim et al., (2023). Improved supply chain integration may boost performance. Internet of things improves performance (De Vass, Shee, & Miah2018). As per the above discussion, the hypothesis is suggested: Hypothesis 5: There is a significant positive relation among internet of things and digital integration. Hypothesis 6: There is a positive association among digital integration and performance. Hypothesis 7: There is a partial mediating relation of digital supply chain integration among sustainable supply chain performance and the internet of things.

RESEARCH METHODOLOGY

This present study shows influences of the internet of things on sustainable performance in manufacturing organizations in the Pakistan. It is investigating the mediation role of competitive advantages and digital supply chain integration. Respondent's personal information was confidential throughout the data collection method (Saddique et al., 2023; Shafiq et al., 2022). The surveys were sent through Google Forms to many corporations in the Pakistan. Data consists of study sample sizes of 369. The study findings are shown in below.



Conceptual Model

Table.3.1 Items and variable detail

Variable	Items	Reference
(Internet of Things)	"4"	(Singh et al., 2021)
(Digital Supply Chain Integration)	"4"	(Lee, S. Y. 2021).
(Competitive advantages)	"4"	(Saddique et al., 2023)
(Sustainable SC Performance)	"4"	(Ma et al.,2022)

Table: 3.2. Demographic Status

"Particular"	**"Characters"**	**"F"**	**"%"**
"Gender"	Female	115	31.2
	Male	254	68.8
"Ages"	Less than 25	68	18.4
	26-40	180	48.8
	41-55	76	20.6
	Above than 55	45	12.2
"Education level"	Less than Intermediate	17	4.60
	Intermediate	34	9.2
	Less than Post Graduate	161	43.6
	Above than post-Graduation	157	42.5
"Work Experience"	< 1 Years	52	14.1
	<5 Years	119	32.2
	< 10 Years	126	34.1
	>than 10 Years	72	19.5

Explanation

Table 3.2 The survey findings indicate the demographic status of the 369 respondents. Of the total, 254 individuals were male (68.8%), while 115 were female (31.2%). The ages of the participants were categorized into five distinct groups: 48.8% of respondents were between the ages of 26 and 40, while 12.2% were above the age of 55. The qualification categories are categorized into four distinct groups. Most respondents, comprising 43.6%, have university graduation degrees, while a minor proportion of respondents, 4.60%, have less than intermediate. Based on work knowledge, it is divided into four categories. It has less than 10 years of experience, accounting for 34.01% of the total. Conversely, the most minor proportion of respondents, 19.05%, have less than one year of experience.

Table#, 3.3: Analysis of Reliability

"Study Variables"	**"Cronbach's Alpha"**
Internet of Things	"0.72"
SC Integration	"0.90"
Competitive Advantages	"0.72"
Sustainable SC Performance	"0.79"

Explanation

Table 3.3 examined "the reliability of the above scale through Cronbach's alpha". findings above exceeded 0.70, indicating that the measurements demonstrated data dependability and reliability and were appropriate for further investigation.

Table#, 3.4 Correlation

"Variables"	1	2	3	4
1. Internet of Things	1			
2. Supply Chain Integration	0.866**	1		
3. Competitive Advantages	0.742**	0.830**	1	
4. Sustainable Supply Chain Performance	0.532**	0.573**	0.564**	1

* Significant = 0.05, **Significant = 0.01.

Explanation

Table#3.4 shows the correlation significance between the internet of things and digital integration "r=0.866, p= 0.00" and the association significance among the internet of things and competitive advantage "r=0.742, p= 0.00". In contrast, association shows significance among the internet of things and sustainable performance with "r=0.532, p= 0.00". Moreover, the correlation shows significant digital integration and competitive advantages "r=0.830, p= 0.00". In contrast, the correlation shows significance among integration and sustainable performance with "r=0.573, p= 0.00", and the correlation shows significance between competitive advances and sustainability with "r=0.564, p= 0.00".

REGRESSION ANALYSIS

Model between Internet of things and Sustainable SCP

Variable	R^2	beta	t	sig
Internet of things	0.283	0.532	12.005	0.000

*Variable Dependent: Sustainable SCP "*p < 0.05".*

Explanation

Table 3.5.1 presents the results of a regression study of an internet of things on sustainable SCP. The statistical significance of the model is shown by an "ANOVA" value of p <0.05. Correlation (R-square) is .283 shows a positive relation among increase in the IoT and sustainable SCP by 28.3%. and p value = 0.00, suggesting that IoT and sustained performance since it falls below the predetermined threshold of 0.05. The beta coefficient of 0.532 indicates a significant relation among IoT and sustainable SCP. Therefore, hypothesis 1 is confirmed.

Model Between Internet of Things and Competitive Advantages

Variable	**R^2**	**Beta**	**t**	**sig**
Internet of things	0.749	0.866	33.08	0.00

*Variable Dependent: Competitive Advantage, "*p < 0.05".*

Explanation

The impact of IoT on competitive advantages shown in Table 3.5.2. The significance value of the "ANOVA is < 0.05", suggesting this may be considered a significant result. The R-squared value .749 shows that IoT has 74.9% influence on competitive advantages. Statistical significance of the coefficient is 0.000, which is below the threshold of 0.05, suggesting a significant association. The beta coefficient, with a value of 0.749, signifies the impact IoT on competitive advantages. Thus, Hypothesis 2 is seen to be acceptable.

Model between Competitive Advantages and Sustainable SCP

Variable	**R^2**	**B**	**t**	**sig**
Competitive Advantages	0.329	0.573	13.40	0.000

*Dependent Variable: Sustainable Supply Chain Performance, *p < 0.05.*

Explanation

The regression analysis findings examining the influence of competitive advantage on sustainable SCP are shown in Table 3.5.3. The "ANOVA < 0.05". "R-squared" =0.329 shows a significant association between the increase in competitive advantages and the corresponding increase in Sustainable SCP by 32.9%, indicating a statistically significant correlation between the variables since it falls below the predetermined threshold of 0.05. The beta coefficient 0.573 suggests a positive relation among competitive advantages and sustainable SCP. Hypothesis# 3, has been accepted.

THE ANALYSIS OF MEDIATION:

"Table 3.5.4": "Mediation analysis using through Bootstrap"

"Relationships"	***"β"***	***"P"***	**Bootstraps @ 95%**		**"Hypotheses"**
			"LL"	**"UL"**	
IOT→CA→SSCP					
"Direct effect"	"0.168	***	0.167	0.417"	
"Indirect effect"	"0.402	***	0.240	0.561"	

Note: *"IOT=Internet of things, CA= Competitive Advantage, SSCP=Sustainable Supply Chain Performance" ***p<0.01*

Explanation

One thousand bootstraps evaluated the variable representing the mediating hypothesis at a 95% confidence level to determine the upper and lower bounds. Competitive advantages mediate among IoT and the sustainable performance. Hypothesis H4 is accepted since impact is indirect ("0.168, LL= 0.167, UL = 0.417, P=0.00"), with less direct effect ("β = 0.168, P=0.00"). Additionally, "0" is absent within both limits, which further supports this conclusion. Competitive advantages have a partially mediated association between competitive advantages and sustainable SCP.

"Model Between Internet of things and Digital Supply Chain Integration"

Variable	**R^2**	**B**	**t**	**Sig**
Internet of things	0.549	0.742	21.15	0.000

*Dependent variable: Digital Supply chain integration, "*p < 0.05".*

Explanation

The result evaluates the IoT on DSCI. In Table 3.5.5, the Significance "ANOVA = 0.05". "R-squared =.549" suggests marginal increase unit one in the internet of things variable is associated with increases of 54.9% with DSCI. "Beta value 0.74. Thus, Hypothesis H5 is deemed valid**.**

"Model between Digital Supply chain integration and Sustainable Supply Chain Performance"

Variable	**R^2**	**B**	**t**	**Sig**
Digital Supply chain integration	0.316	0.564	13.087	0.000

*Dependent Variable: "Sustainable Supply Chain Performance, *p < 0.05".*

Explanation

According to Table 3.5.6, the regression analysis demonstrates the influence of DSCI ON SSCP. The significance value "ANOVA = 0.05". "R-squared = .316 is used, signifying that a single-unit change in supply chain integration would result in a 31.6% Sustainable SCP. Beta coefficient 0.564 suggests a positive among DSCI and SSCP. Hypothesis H6 has been accepted.

ANALYSIS OF MEDIATION

"Table 5": "Mediation analysis using through Bootstrap"

"Relationships"	***"β"***	***"P"***	**Bootstraps @ 95%**		**"Hypotheses"**
			"LL"	**"UL"**	
IOT→DSCI→SSCP					
"Direct effect"	"0.320	***	0.148	0.493"	
"Indirect effect"	"0.467	***	0.311	0.625"	

Note: *"IOT=Internet of Things, =, DSCI= Digital Supply Chain Integration, SSCP =Sustainable Supply Chain Performance, ***p<0.01"*

Explanation

A 95% confidence interval was used to test the mediation hypothesis, with 1000 bootstraps used to define lower and upper limits. The association among IoT and Sustainable SCP is mediated by digital supply chain integration. This mediating role has an indirect impact, as shown by a coefficient of 0.467, a lower limit of 0.311, an upper limit of 0.625, and an implication level of 0.01. The observed effect is statistically

significant: beta is 0.467, and p is 0.00. Hypothesis H7 has been confirmed. The research determines that digital integration has a partial positive relationship among IoT and sustainable SCP.

DISCUSSION

Digitalization is essential for efficiency. Digital technologies may improve supply performance. IoT utilized everywhere in supply chain networks. IoT improves the IT systems. Organizations use IoT-driven business models that access sensing devices. A complete digitalization system improve performance includes the IoT. A digital approach helps organizations progress. This study examines how supply chains might improve organizational performance by integrating the IoT. This research examined IoT providers to confirm the expected positive and substantial direct linkages and intermediary effects. This empirical study answered the first research question by showing that IoT adoption's advantages and obstacles improve digital integration (Lee et al., 2022; De Vass et al., 2018). Additionally, digital integration improves performance and competitive advantage. Due to its cooperation, collaboration, and cooperative culture, supply chain integration provides organizations with a competitive market edge (Abdallah et al., 2023). IoT adoption is significant with performance; it is associated with managing activities. With IoT with digital integration might help companies respond changes, satisfy customer expectations, and compete more effectively (DeVass et al., 2018). Integration technologies may boost supply chain and organizational performance (Kamble et al., 2023). Digital integration improves performance (Boubker, O. 2022). Companies may link supply chains with suppliers and customers through IoT-powered digital infrastructure. IoT helps improve efficiency (Abdel-Basset et al.,2018). Digital integration helps in gaining advantage through digitalization (Haddud et al., 2017). Digital integration improves performance (Sultana & Rahman, 2018). IoT adoption with integration on performance (Shafique et al., 2018). Additionally, IoT adoption partially mediates competitive advantage and sustainability (Tukamuhabwa et al., 2021). Digital integration strongly and partially mediated the link between IoT adoption advantages (DeVass et al., 2018). This technology synchronizes information flow in worlds. Due to IoT device’s massive information output, a company may need help with data management (Lee et al., 2022). Additionally, the capacity quickly accepts internet of thing fast development that boost its competitiveness (Haddud et al., 2017). SSCP is mediates the association among integration and performance (Mathur et al., 2018). As (Yunus et al., 2016), competitive advantage partly influences digital integration and effectiveness. Significantly, digital integration and competitive advantages serially mediated IoT adoption benefits and sustainable performance.

6. Conclusions: It is prepared to use the internet of things helpful in different fields and areas. This study provided a methodology for studying IoT's impact performance. This research emphasizes supply chain integration and internet of thing influence on firm performance. Digital integration is effectively sharing data internally and with partners and customers, which requires trust and openness. Integrations boost competitiveness and sustainability. The IoT has significant influence on sustainability. Furthermore, digital integration and competitive advantages partially mediate between IoT and SSC performance. IoT

increases organizational success with supply chain integration. IoT advantages boost competitiveness and operational effectiveness.

Theoretical Implication

This study illuminates that IoT adoption increase sustainability through competitive advantage and digital integration. Firm use internet of thing delivers inventory and logistical data, improving supply chain integration. It aids data-driven supply chain, organizational, and market competitiveness decisions. This research addresses critical gaps on IoT adoption, digital integration, and operational success, providing valuable theoretical insights. Instead of studying these subjects independently, this study investigates their relationships to show how firms may increase performance by utilizing the IoT.

Practical Implications

The significant implications for companies advocating for the adoption of internet of thing in integration. Given its widespread use, the IoT's external integration is crucial performance. The study also underscores IoT as a competitive edge, enabling companies to stay ahead of technological advancements and industry peers. All supply chain participants leveraging IoT technology can enhance performance. IoT technologies accelerate the evolution of intelligent supply chains, equipping organizations with essential capabilities and advancing the IoT in this industry. Rapid growth ensures sustainability and generates comprehensive data for future progress analysis.

Limitations and Future Research Directions

This research analyzed the advantages of IoT influence on efficiency of organizational adaption, and technological dependability. Further research is needed advantages and drawbacks of internet of thing on supply chain management. Limitations include the limited sample size. Despite these constraints, our work is a significant theoretical addition to the resource-based approach & organizational capacities. This article shows how internet of thing and digital integration generates long term competitive advantage and improve sustainable performance.

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