Supply chain integration and IT competency of maritime organisations: the adoption of blockchain technology

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1. Purpose: This paper aims to achieve two primary objectives. Firstly, the research explores the current state of blockchain adoption in different maritime organisations. Secondly, the study aims to develop the relationship between supply chain, information technology competency and performance within maritime organisations. Finally, it seeks to examine the effect of blockchain technology adoption in enhancing maritime supply chain integration.

2. Research approach: This study is grounded in a Resource Based View (RBV), which posits that maritime organisations can achieve enhanced performance by deploying appropriate Information Technology (IT) competency that aligns with their level of supply chain integration. A survey instrument was elaborated and data was collected from a total of 334 samples within maritime organisations in Korea, including, shipping liners, terminal operators, forwarding companies, and port authorities. This study employed One-way ANOVA tests to examine the differences in blockchain adoption among four groups of maritime organisations. Then, PLS-SEM method is deployed to examine the impact of IT competency on supply chain integration and supply chain integration on performance. Additionally, the research investigates the potential moderating(interaction) effects between the utilisation of blockchain technology in the relationship between supply chain integration and IT competency.

3. Finding and originality: This study identifies significant role of IT competency on performance through its impact on maritime supply chain integration. in maritime supply chain. The research findings determine that blockchain strengthens supply chain integration in maritime organizations by leveraging their IT competency. This research is the first paper to empirically validate the effects of blockchain adoption in the maritime industry from the perspective of supply chain integration.

4. Research impact: This study extends the existing contingency research on supply chain integration and IT especially in the maritime sector. This research provides a significant academic contribution by examining the effect of blockchain technology on the relationship between supply chain integration, IT competency fitness, and performance in the maritime industry. Specifically, the study explores the moderating role of blockchain technology in this relationship, which is an area that has not been well-researched. The empirical findings of the study advance the current literature on supply chain integration and digitalisation by demonstrating the configuration of supply chain integration and IT competency, and potential of blockchain technology to improve supply chain processes and enhance overall performance.

5. Practical impact: This study is expected to offer insights into the strategies for IT competency development among maritime organisations at strengthening the integration of the supply chain in response to the forthcoming digitalistion. Additionally, it is poised to provide insights into to the tangible effects of blockchain technology, which is being steadily introduced in the maritime industry.

6. Keywords: Maritime; supply chain integration; IT competency; Blockchain

1. Introduction

In recent years, major shipping organisations have adopted blockchain technology (BTC) to integrate maritime supply chain for end-to-end service (Panayides and Song 2009). Shipping companies are developing BCT-based platform where encrypted data can be accessible to every party reducing inefficiency including time delay, human error, and miscommunication. Notwithstanding the diffusion of BCT application academic research of blockchain application in the maritime and shipping industry is still in fancy. While a wide range of literature has conducted conceptual and review analysis and provided valuable insights, there has been far less consideration in maritime sphere.

2. Literature review

2-1. Maritime supply chain integration

Supply chain integration (SCI) in the maritime and shipping sector has become a predominant strategy in response to changing customer needs. SCI denotes the extent to which a company effectively utilise its resources and capability in a collaborative manner with its channel partners. While early SCI focused on the linear relationship and flows between customers and suppliers more recent developments emphasise a non-linear network approach to integration (Fabbe-Costes and Jahre 2008). SCI in maritime supply chain consists of Information sharing, Knowledge creation, Collaborative communication, Goal similarity, Decision harmonisation, Joint chain performance measurement (Seo et al. 2016). Information sharing among stakeholders facilitates seamless cargo flows in the maritime supply chain by contributing to visibility and exchanging relevant and accurate information (Heide and John 1992). Knowledge creation plays a vital role in the maritime supply chain by enabling participants to engage in inter-organisational collaboration, generating and acquiring integrated knowledge that empowers them to effectively mitigate uncertainty and adapt to the dynamic changes within the supply chain (Lee and Song 2010). Collaborative communication, serving as the foundation for integrated strategies within the maritime supply chain, facilitates interaction among stakeholders, enabling effective supply chain operations, strategic formulation, and decision making (Cao and Zhang 2011). Goal similarity in maritime supply chain refers to extend to which participants pursue common objectives, aiming to improve the efficiency and effectiveness of the entire supply chain (Ryu et al. 2009). This pursuit maximises the benefits derived from SCI. Through decision harmonisation, stakeholders strategically align transport planning and operations across the maritime supply chain, aiming to secure transport volume from external supply chains and foster mutual benefits in a competitive environment (Song and Panayides 2008). Jointly measuring and managing the performance of a supply chain contributes to the establishment of contingency plans and modifications in order to optimise the flow of cargos within the supply chain. It enhances visibility within the supply chain and enables the evaluation of collaborative efforts by diagnosing supply chain operations (Simatupang and Sridharan 2005).

2-2. IT competency

IT competency encompasses a firm's ability to gather, integrate, and utilise IT resources effectively in order to address business requirements and leverage potential business prospects. IT competency consists of flexible IT infrastructure, IT assimilation, managerial IT knowledge, and IT personnel skills considering supply chain context (Liu et al. 2016). Flexible IT infrastructure denotes a shared set of technological resources that form the foundation for the prompt development and implementation of both present and future IT applications(Terry Anthony Byrd 2000). IT Assimilation refers to a firm's ability to effectively utilise IT to support, shape, and facilitate its business strategies and value chain activities. Top managers'

managerial IT knowledge encompasses essential business acumen and technical skills to perceive the value and potential of IT and effectively employ it to align business processes with organisational goals (Lee et al. 1995). IT personnel skills denotes the technical capabilities of IT staff that assist companies in integrating IT platforms, data, and information systems to effectively address the challenges posed by the rapid growth and widespread adoption of innovation (Lee et al. 1995).

2-3. Blockchain adoption and utilisation

Blockchain utilise a decentralised network to maintain and track transaction data, with blocks in the chain linked by cryptographic hashes and all nodes having an identical copy. Once verified and validated by the parties involved in the transactions, blocks become immutable, ensuring transparency, traceability, security, and trust over the network. Data on a decentralised system can be accessed, monitored, stored, and updated by multiple participants, resulting in disintermediation of intermediaries and full visibility of transactions for supply chain members (Blossey et al. 2019). Based on a systematic literature review conducted prior to this study, the application of blockchain in the maritime supply chain has been identified and categorized into three domains based on specific roles and associated benefits: document management, transaction management, and cargo, vessel, and terminal operation.

2-4. Performance

In this study, the measurement of organisational performance entailed assessing the effectiveness of supply chain operations and the degree of financial benefits. Operational performance indicators included the speed, cost reduction, quality, and lead time within the supply chain. Financial performance was evaluated based on metrics such as return on investment, return on sales, market share, and net income, among others (Flynn et al. 2010).

3. Research method

A survey instrument was elaborated based on the literature review and conceptual framework developed from review analysis. SCI in maritime supply chain consists of Information sharing, Knowledge creation, Collaborative communication, Goal similarity, Decision harmonisation, Joint chain performance measurement. IT competency consists of flexible IT infrastructure, IT assimilation, managerial IT knowledge, and IT personnel skills considering supply chain context. Data was collected from a total of 334 samples within maritime organisations in Korea, including, shipping liners, terminal operators, forwarding companies, and port authorities. This study employed One-way ANOVA tests to examine the differences in blockchain adoption status among four groups of maritime organisations. Then, PLS-SEM method is deployed to examine the impact of IT competency on supply chain integration and supply chain integration on performance. Additionally, the research investigates the potential moderating(interaction) effects between the utilisation of blockchain technology in the relationship between supply chain integration and IT competency. Research model and hypothesis are established as followed:

H1: IT competency positively influences Supply chain integration.
H2-1: Supply Chain Integration positively influences operational performance.
H2-2: Supply Chain Integration positively influences financial performance.
H3-1: IT competency indirectly influences operational performance through its impact on supply chain integration.
H3-2: IT competency indirectly influences financial performance through its impact on supply chain integration.
H4: Blockchain technology adoption enhances the relationship between IT competency and Supply chain integration, leading to improved performance.

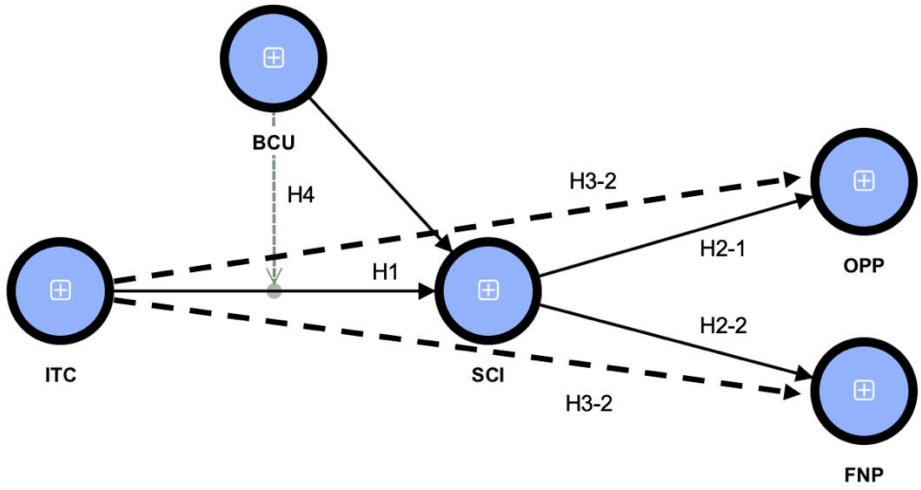

Figure1. Research model

4. Findings

A One-way ANOVA was conducted to examine the differences in the variable BCU among four groups (shipping liner, freight forwarder, terminal operator, port authority). The analysis did not revealed a significant effect of group on BCU.

Dependent valuable	Business type	N	Mean	SD	F	P
Blockchain Utilisation	Shipping Liner	78	3.819	1.585	1.974	.118
	Freight Forwarder	116	3.695	1.411		
	Terminal Operator	56	3.187	1.700		
	Port Authority	29	3.742	1.872		

Table. Differences in blockchain utilisation between the maritime organisations

As the next step, the questionnaire survey was conducted and the measurement model was assessed to establish the reliability and validity of the construct. All items in the model exhibited factor loadings greater than the recommended value of 0.70. Reliability analysis using Cronbach's alpha and composite reliability (C.R) yielded values exceeding the threshold of 0.70, demonstrating high internal consistency. Convergent validity was supported as the average variance extracted (AVE) exceeded the acceptable threshold of 0.50 (Hair et al. 2010). Discriminant validity was established by comparing the correlations among latent variables with the square root of AVE (Fornell and Larcker 1981). The correlations were lower than the corresponding AVE, confirming discriminant validity. Higher-order constructs were formed for SCI and IT competency, comprising 6 and 4 lower-order constructs, respectively. To establish the validity of these higher-order constructs, factor loadings, reliability, and convergent validity were examined. The indicators exhibited factor loadings higher than the desired threshold of 0.70, ensuring strong associations. Reliability analysis using Cronbach's alpha and C.R indicated values above 0.70, demonstrating good internal consistency for the higher-order constructs. Convergent validity was supported as the AVE for the higher constructs exceeded 0.50. Discriminant validity was established by comparing the correlations among latent variables with the square root of AVE. The square root of AVE for each construct was higher than its correlation with all other constructs, confirming discriminant validity.

Categories	Latent variables	No. items	Reliability & Validity

			Cronbach's alpha	C.R	AVE
SCI	Information Sharing (IS)	5	0.907	0.931	0.729
	Knowledge Creation (KC)	5	0.89	0.919	0.694
	Collaborative Communication (CC)	5	0.897	0.924	0.708
	Goal Similarity (GS)	5	0.876	0.909	0.668
	Decision Harmonisation (DH)	5	0.871	0.906	0.659
	Joint chain Performance Measurement (JPM)	5	0.861	0.9	0.643
ITC	Flexible IT Infrastructure (FITI)	5	0.906	0.93	0.727
	IT Assimilation (ITA)	4	0.923	0.946	0.813
	Managerial IT Knowledge (MITK)	3	0.954	0.97	0.916
	IT Personnel Skills (ITPS)	5	0.953	0.964	0.842
BCA	Blockchain Untilisation (BCU)	4	0.968	0.977	0.914
PERF	Operational Performance (OPP)	6	0.94	0.953	0.771
	Financial Performance (FNP)	5	0.967	0.974	0.883

Table. Construct of questionnaire and Reliability / Validity

Following the assessment of the measurement model, the evaluation of structural paths and the examination of path coefficients were conducted. H1 aimed to investigate the significant and positive effect of IT competency on SCI. The results indicated a significant and positive impact of IT competency on SCI ($\beta = .562$, $t = 10.602$, $p < 0.000$), providing support for H1. Next, H2-1 and H2-2 examined the significant and positive effects of SCI on operational performance and financial performance, respectively. The findings revealed significant and positive impacts of SCI on operational performance ($\beta = .723$, $t = 19.965$, $p < 0.000$) and financial performance ($\beta = .656$, $t = 14.862$, $p < 0.000$), thereby supporting H2. Moving on to H3-1 and H3-2, the indirect effects of ITC on operational performance and financial performance through SCI were assessed. The analysis demonstrated that IT competency indirectly enhances operational performance ($\beta = .406$, $t = 9.658$, $p < 0.000$) and financial performance ($\beta = .369$, $t = 9.392$, $p < 0.000$) through its positive impact on SCI, providing support for H3. Furthermore, H4 examined the moderating effect of BCT adoption on the relationship between IT competency and SCI. The analysis revealed a significant positive interaction effect of BCT on the IT competency - SCI relationship ($\beta = .201$, $t = 4.510$, $p < 0.000$), indicating that the relationship between IT competency and SCI is strengthened when BCT is highly utilised. This finding supports H4 and suggests that BCT adoption acts as a moderator.

Hypothesis	Path	β	S.E	T	P
H1	ITC -> SCI	0.562	0.053	10.602	0.000
H2-1	SCI -> OPP	0.723	0.036	19.965	0.000
H2-2	SCI -> FNP	0.656	0.044	14.862	0.000
H3-1	ITC -> SCI -> OPP	0.406	0.042	9.658	0.000
H3-2	ITC -> SCI -> FNP	0.369	0.039	9.392	0.000
H4	BCU x ITC -> SCI	0.201	0.045	4.51	0.000

Note. β = beta coefficient, S.E = Standard Error, T = t-statistics, P = Probability value, *Relationships are significant at P<0.001

Table 3. Data analysis results

5. Conclusion

This study extends the existing contingency research on SCI and IT especially in the maritime sector. This research provides a significant academic contribution by examining the effect of blockchain technology on the relationship between SCI and IT competency. the study explores the moderating role of blockchain technology in this relationship, which is an area that has not been well-researched. The empirical findings of the study advance the current literature on supply chain integration and digitalisation by demonstrating the configuration of SCI-IT competency and potential of blockchain technology to improve supply chain processes and enhance overall performance.

However, it is important to acknowledge certain limitations of this study. One notable limitation is the relatively low adoption and utilisation of blockchain technology in the maritime sector, which may raise concerns regarding the generalisability of the research findings. The limited understanding of blockchain technology and its applications among the respondents is a potential limitation in this study. Furthermore, due to the rapidly evolving nature of blockchain technology, the current study's findings may have a limited shelf life. As blockchain technology continues to advance and mature, new developments and implementations may emerge, potentially impacting the observed relationships and outcomes.

References

Blossey, G. et al. 2019. Blockchain technology in supply chain management: an application perspective.

Cao, M. and Zhang, Q. 2011. Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of operations management* 29(3), pp. 163-180.

Fabbe-Costes, N. and Jahre, M. 2008. Supply chain integration and performance: a review of the evidence. *The International Journal of Logistics Management*,

Flynn, B. B. et al. 2010. The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of operations management* 28(1), pp. 58-71.

Fornell, C. and Larcker, D. F. 1981. Structural equation models with unobservable variables and measurement error: Algebra and statistics. Sage Publications Sage CA: Los Angeles, CA.

Hair, J. et al. 2010. Multivariate Data Analysis: A Global Perspective (7th eds.) Pearson Education Inc. *Upper Saddle River, New Jersey*,

Heide, J. B. and John, G. 1992. Do norms matter in marketing relationships? *Journal of marketing* 56(2), pp. 32-44.

Lee, D. M. et al. 1995. Critical skills and knowledge requirements of IS professionals: A joint academic/industry investigation. *MIS quarterly*, pp. 313-340.

Lee, E.-S. and Song, D.-W. 2010. Knowledge management for maritime logistics value: discussing conceptual issues. *Marit. Pol. Mgmt.* 37(6), pp. 563-583.

Liu, H. et al. 2016. The configuration between supply chain integration and information technology competency: A resource orchestration perspective. *Journal of operations management* 44, pp. 13-29.

Panayides, P. M. and Song, D.-W. 2009. Port integration in global supply chains: measures and implications for maritime logistics. *International Journal of Logistics: Research and Applications* 12(2), pp. 133-145.

Ryu, I. et al. 2009. The role of partnership in supply chain performance. *Industrial Management & Data Systems*,

Seo, Y.-J. et al. 2016. The influence of supply chain collaboration on collaborative advantage and port performance in maritime logistics. *International Journal of Logistics Research and Applications* 19(6), pp. 562-582.

Simatupang, T. M. and Sridharan, R. 2005. The collaboration index: a measure for supply chain collaboration. *International Journal of Physical Distribution & Logistics Management*,

Song, D.-W. and Panayides, P. M. 2008. Global supply chain and port/terminal: integration and competitiveness. *Maritime Policy & Management* 35(1), pp. 73-87.

Terry Anthony Byrd, D. E. T. 2000. Measuring the flexibility of information technology infrastructure: Exploratory analysis of a construct. *Journal of Management Information Systems* 17(1), pp. 167-208.