Journal of Public Representative and Society Provision
Vol. 6, Issue 2, 2026
Page 354-374
Doi: https://doi.org/10.55885/jprsp.v6i2.884

The Moderating Role of Digital Supply Chain and Biodiesel Policy on Fuel Supply Chain Performance in the N-PSO Sector

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Abstract. *The implementation of Indonesia's mandatory biodiesel policy has increased the complexity of fuel supply chain management, particularly in the Non-Public Service Obligation (N-PSO) sector, which operates without price subsidy support. This condition requires strong process integration and operational capability to maintain supply chain performance amid policy dynamics and supply risks. This reserach aims to analyze the effect of supply chain integration on fuel supply chain performance in the N-PSO sector, with supply chain capability as a mediating variable and digital supply chain and biodiesel policy as moderating variables. A quantitative approach was employed using primary data collected through a questionnaire survey of several fuel trading companies and their contractors who are acting under the national biodiesel blending mandate in Indonesia. Data were analyzed using PLS-SEM modeling. The results indicate that supply chain integration has a positive and significant effect on supply chain capability and supply chain performance, and supply chain capability mediates this relationship. Digital supply chain is not proven to moderate the effect of supply chain integration on supply chain capability. In addition, biodiesel policy does not moderate the effect of supply chain capability on supply chain performance. These findings indicate that improvements in supply chain performance in the N-PSO sector are mainly driven by internal integration and operational capability rather than by the moderating role of digitalization and policy intervention.*

Keywords: *Biodiesel Policy, Supply Chain Integration, Supply Chain Capability, Supply Chain Performance, Digital Supply Chain*

Received: January 22, 2026 Revised: February 04, 2026 Accepted: March 24, 2026

INTRODUCTION

The Indonesian government's mandatory biodiesel policy is a key instrument for accelerating the transition to renewable energy, reducing fossil fuel dependency, and strengthening national energy security (Fahmi, 2025; Veza et al., 2025; Kumar et al., 2013). Progressive blending mandates from B20 to B40 and projected toward B50 have significantly increased biodiesel distribution volumes and reshaped the structure and complexity of the national fuel supply chain. These changes pose substantial challenges for the the Non-Public Service Obligation (N-PSO) sector, which operates under market-based mechanisms without direct price subsidies. Volatile crude palm oil prices, shifting subsidy schemes, and regulatory dynamics intensify cost pressures, operational risks, and coordination complexity along the N-PSO fuel supply chain.

ISSN 2776-1266 (print), 2776-1266 (online)

Empirical evidence shows that Indonesia's biodiesel supply chains remain vulnerable due to infrastructure limitations, logistics disruptions, quality risks, and suboptimal coordination among actors (Agustina et al., 2023; Ardiansah & Pujawan, 2024). Weak information sharing and limited coordination lead to supply–demand mismatches, longer lead times, and deteriorating supply chain performance (Datta & Christopher, 2011; Vosooghidizaji et al., 2020; Costantino et al., 2014; Arshinder et al., 2011). In this context, supply chain integration becomes critical for aligning internal processes with external relationships with suppliers and customers. However, the extent to which N-PSO firms can respond effectively to policy-driven changes depends not only on integration but also on how far integration is translated into robust operational capabilities and is supported by digital infrastructures and regulatory frameworks.

Most existing studies examine supply chain integration, supply chain capability, and supply chain performance in generic manufacturing or technical settings, whereas empirical models that simultaneously incorporate digital supply chain and biodiesel policy variables in renewable energy contexts remain scarce. Consequently, there is limited understanding of how internal integration and capability interact with digital infrastructures and policy frameworks to shape fuel supply chain performance in the N-PSO sector. Therefore, this study analyzes the effect of supply chain integration on fuel supply chain performance in the Indonesian N-PSO sector, with supply chain capability as a mediating variable, and digital supply chain and biodiesel policy as moderating variables. The research may contribute to renewable energy supply chain management by offering an integrated model that captures internal, technological, and policy dimension by providing strategic insights for practitioners and policymakers to design more resilient and high-performing biodiesel supply chains.

Relationship with Supply Chain Management and Digital Technology

This topic sits at the intersection of supply chain management and digital technology because it integrates three core dimensions, such as internal process alignment (supply chain integration), organizational competencies (supply chain capability), and digital technologies that enable information flow and coordination. Classical supply chain management emphasizes synchronized material, information, and financial flows across functional silos and firm boundaries to reduce costs and improve service levels (Chopra & Meindl, 2021).In biodiesel distribution, such synchronization is critical due to the sensitivity of biodiesel quality to handling conditions, the need for precise blending ratios, and the coordination of storage and transportation infrastructure (Agustina et al., 2023).

Digital operations research highlights the role of data-driven systems, real-time visibility, and advanced analytics in enhancing decision-making and responsiveness (Bahrami et al., 2022; Cui et al., 2024). Integrated digital platforms enable firms to monitor inventory levels, track shipments, forecast demand, and coordinate production plans across multiple actors. For N-PSO fuel distributors, digitalization supports planning amid policy-driven demand shifts, mitigates logistics disruptions, and improves responsiveness to market price volatility. However, the extent to which digital tools translate into performance gains depends on their alignment with existing processes, organizational capabilities, and regulatory conditions (Shahadat et al., 2023). Positioning digital supply chain as a moderator in this study is consistent with contemporary views that technologies do not yield uniform benefits, but instead condition the strength of relationships between integration, capabilities, and performance in heavily regulated, asset-intensive sectors such as energy.

Supply Chain Integration, Supply Chain Capability, and Supply Chain Performance

Supply chain integration (SCI) refers to the extent to which a firm coordinates its activities with those of other firms in its supply chain (Jayaram et al., 2010; Alfalla-Luque et al., 2013; Fabbe-Costes & Jahre, 2018; Leuschner et al., 2013). It harmonizes its internal functional activities (internal integration) and collaborates with external partners such as suppliers, logistics providers, and customers (external integration) (Cui et al., 2023; Ghariani et al., 2025;

Khanuja & Jain, 2022; Liao et al., 2022). High levels of SCI reduce information asymmetry, align incentives, and enable joint problem-solving across the supply chain (Khanuja & Jain, 2022; Phan et al., 2020). Empirical studies show that SCI improves forecast accuracy, reduces lead times, and increases reliability and flexibility, thereby enhancing overall supply chain performance (Liao et al., 2022).In the biodiesel context, integration supports stable feedstock procurement, coordinated blending operations, and synchronized distribution scheduling, which are crucial for ensuring product quality and on-time delivery (Agustina et al., 2023). Accordingly, this study proposes:

H1: Supply chain integration has a positive effect on supply chain performance.

Integration must, however, be supported by supply chain capabilities (SCC) to realize the performance benefits fully (Wook, 2006; Huo, 2012; Oubrahim et al., 2023). SCC encompasses a firm's ability to manage flexibility, responsiveness, coordination, and risk under dynamic conditions (Juan et al., 2022; Luqman et al., 2023). These capabilities are embedded in operational routines, decision-making processes, and learning mechanisms that allow firms to adapt to disruptions, policy changes, and market fluctuations (Zhao et al., 2023; Lin & Fan, 2024). (Liao et al., 2022) provide empirical evidence that SCI strengthens SCC, which, in turn, enhances performance, indicating a mediating role for capability. In biodiesel N-PSO operations, integrated firms can better synchronize production and distribution plans. However, only those with strong capabilities can translate integration into effective contingency planning, demand responsiveness, and risk (Agustina et al., 2023; Khanuja & Jain, 2022; Liu et al., 2022). Therefore, the study further posits:

H2: Supply chain integration has a positive effect on supply chain capability.

H3: Supply chain capability has a positive effect on supply chain performance.

H4: Supply chain capability positively mediates the effect of supply chain integration to supply chain performance.

Digital Supply Chain as an Enabling Infrastructure

Digital supply chain (DSC) refers to the use of integrated information systems, real-time data sharing platforms, Internet of Things (IoT) devices, and analytics tools to support coordination and decision-making across the supply chain (Bahrami et al., 2022; Hijjawi et al., 2023). Empirical evidence suggests that DSC adoption enhances visibility, improves collaboration, and increases responsiveness, thereby contributing to improved performance (Jing & Fan, 2024; Shahadat et al., 2023). Cui et al. (2024) show that data-driven analytics capabilities strengthen the effect of integration on responsiveness by improving information processing and decision quality.

In biodiesel distribution, DSC enables real-time monitoring of stock levels at depots and stations, shipment tracking, monitoring of blending operations, and more accurate forecasting under fluctuating demand and policy conditions. However, studies indicate that the benefits of DSC are contingent on organizational readiness, process alignment, and the maturity of digital platforms (Shahadat et al., 2024). This suggests that DSC functions as a contextual factor that can strengthen or weaken the extent to which integration is transformed into capabilities. Thus, DSC is conceptualized proposed as a moderating variable affecting the supply chain integration and performance linkage:

H5: Digital supply chain positively moderates the effect of supply chain integration to supply chain capability.

Biodiesel Policy as an External Moderating Factor

Government policy, particularly mandatory biodiesel blending regulations, is a critical external force shaping supply chain structures and behaviors in the Indonesian energy sector (Usmani et al., 2023). Global experiences with biofuel deployment highlight complex trade-offs between energy security, environmental outcomes, and supply chain design (Zheng et al., 2020). Biodiesel policy determines blending targets (e.g., B20, B30, B40), influences subsidy schemes, and sets quality and distribution standards (Husada et al., 2023). These regulations affect cost structures, infrastructure requirements, and coordination patterns across the supply chain. Halimatussadiah et al. (2021) emphasize that policy frameworks may alter how internal capabilities are deployed and monetized, thereby influencing their impact on performance outcomes. While supportive policies and subsidy mechanisms can enhance the effectiveness of firm-level capabilities by reducing financial risk and encouraging investment (Israel & Siwandeti, 2024), stringent or uniform regulations may constrain strategic flexibility and limit differentiation advantages derived from capabilities.

In the N-PSO context, where firms operate under market-based pricing and face higher exposure to cost volatility, the design and implementation of biodiesel policy can either amplify or dampen the performance impact of supply chain capabilities (Raygoza Limón et al., 2025; Yuan & Pan, 2023) On this basis, biodiesel policy is modeled as a moderating variable affecting the supply chain capability to performance linkage:

H6: Biodiesel policy positively moderates the effect of supply chain capability towards supply chain performance

By integrating SCI, SCC, DSC, and biodiesel policy into a single empirical framework, this study contributes to a deeper understanding of how internal processes, organizational competencies, technological infrastructures, and regulatory environments jointly shape fuel supply chain performance in the Indonesian N-PSO sector.

METHODS

Data Collection

This study uses a quantitative explanatory design with a cross-sectional online survey to analyze the causal relationships among Supply Chain Integration (SCI), Supply Chain Capability (SCC), Digital Supply Chain (DSC), Biodiesel Policy (BP), and Supply Chain Performance (SCP) in the Indonesian N-PSO fuel sector. Data was collected using a structured self-administered questionnaire distributed via Google Forms. Structural Equation Modeling with Partial Least Squares (PLS-SEM) was applied to test the research model, as it is suitable for prediction-oriented studies with complex relationships involving mediation and moderation and when multivariate normality cannot be fully assumed (Hair et al., 2019). PLS-SEM allows simultaneous estimation of the measurement and structural models while accounting for measurement error in latent constructs (Asamoah et al., 2021; Bahrami et al., 2022). Data analysis was conducted using SPSS for descriptive statistics and SmartPLS for PLS-SEM. Figure 1 presents the research model, in which SCI predicts SCC and SCP; SCC mediates the relationship between SCI and SCP; DSC moderates the relationship between SCI and SCC; and BP moderates the relationship between SCC and SCP.

ISSN 2776-1266 (print), 2776-1266 (online)

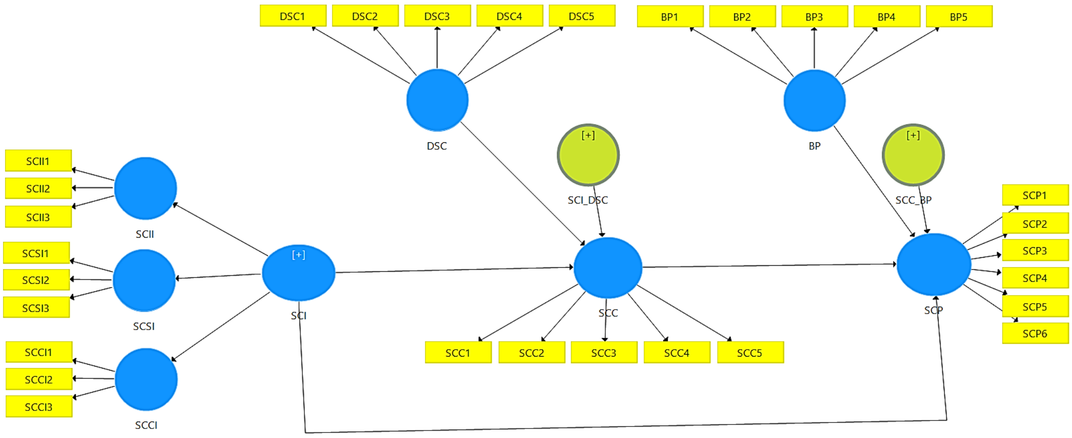

Figure 1. The Research Model

Research Population and Sample

The research population comprises N-PSO fuel trading companies in Indonesia and their employees who are involved in, or support, supply chain-related functions and have been exposed to biodiesel policy and supply chain digitalization between 2020 and 2025. To ensure that respondents had sufficient knowledge of biodiesel distribution and digital supply chain practices, inclusion criteria were defined as shown in Table 1.

Table 1. Description of Primary Data Sources

Aspect	Description
Target Population	Employees of Non-Public Service Obligation (N-PSO) fuel trading companies in Indonesia
Unit of Analysis	An individual employee representing the organization's supply chain practices
Organizational Type	Private/commercial N-PSO fuel trading firms are obligated to distribute biodiesel blends.
Functional Roles	Employees in operations, logistics & warehousing, procurement, inventory control, planning, finance, commercial, or other functions directly supporting fuel supply chain activities.
Experience	Minimum 1 year of work experience in the current organization
Biodiesel Exposure	Directly involved in, or closely supporting, activities related to biodiesel blending, distribution, or compliance with biodiesel mandates (since at least 2020)
Digital Supply Chain Exposure	Familiar with, or involved in, the use of digital tools (e.g., ERP, TMS, WMS, tracking systems, data analytics) in supply chain operations
Policy Awareness	Aware of mandatory biodiesel regulations and their operational and cost implications for the organization
Geographic Scope	Organizations operating within the Indonesian fuel distribution network

A purposive sampling technique was used to ensure that respondents possess sufficient knowledge about supply chain integration, capabilities, digital initiatives, and biodiesel regulation (Agustina et al., 2023; Ardiansah & Pujawan, 2024; Israel & Siwandeti, 2024). Eligible respondents work in functions such as operations, logistics and warehousing, procurement, inventory control, finance, legal, and commercial within N-PSO fuel trading firms obligated to distribute biodiesel blends.

Sample size planning followed multivariate analysis guidelines, recommending at least 5–10 observations per indicator (Hair et al., 2019), as well as standard PLS-SEM rules of thumb.

Accordingly, the study targeted approximately 150–300 valid responses, which is adequate for estimating a complex PLS-SEM model.

Data Sources

Primary data were collected directly from respondents through the online questionnaire. All constructs were modeled as latent variables with multiple indicators adapted from established scales in supply chain management, digital supply chain, and energy policy literature and then contextualized to the N-PSO biodiesel distribution setting (Al Humdan et al., 2020; Bahrami et al., 2022; Liao et al., 2022; Liu et al., 2022; Ning & Yao, 2023; Phan et al., 2020). Items were measured using Likert-type scales. Table 2 summarizes the constructions, their roles in the model, dimensions and its measurement, and key references.

Table 2. Summary of Key Constructs Captured by The Indicators

Construct	Role	Dimensions and Measurement Items		Key References
Supply Chain Integration (SCI)	Independent variable	Internal integration, supplier integration, and customer integration		(Khanuja & Jain, 2022; Liao et al., 2022; Liu et al., 2022)
		SCII1	Our company has established an integrated internal information network to support supply chain activities.	
		SCII2	Our company uses enterprise systems to integrate operational processes across functional units.	
		SCII3	Cross-functional teams in our company work in a coordinated and collaborative manner to support supply chain activities.	
		SCSI1	Our company and key suppliers share information on supply availability, procurement plans, and production schedules.	
		SCSI2	Key suppliers are actively involved in ensuring the effectiveness of procurement processes and product development.	
		SCSI3	Our company maintains long-term strategic partnerships with key suppliers to enhance supply chain quality and stability.	
		SCCI1	Our company regularly exchanges information with customers regarding fluctuations in raw material availability and demand.	
		SCCI2	Our company and customers use structured communication channels to support supply chain coordination.	

ISSN 2776-1266 (print), 2776-1266 (online)

		SCCI3	Our company establishes strategic partnerships with key customers to enhance sustainable supply chain performance.	
Supply Chain Capability (SCC)	Mediator and predictor	Process efficiency, requirement handling capability, contingency planning, agility, and flexibility		(Liao et al., 2022; Luqman et al., 2023; Shahadat et al., 2023)
		SCC1	Our company has the capability to streamline administrative transaction processes with suppliers and customers and eliminate unnecessary or redundant procedures.	
		SCC2	Our company is able to consistently meet customer requirements related to product quality, capacity, and on-time delivery.	
		SCC3	Our company possesses supply chain capabilities to conduct effective contingency planning in order to mitigate supply chain disruptions.	
		SCC4	Our company is able to rapidly adapt to changes in market dynamics through the effective use of digital technologies.	
		SCC5	Our company is able to adjust its operational structure to respond to changes in customer demand or emerging market patterns by leveraging digital technologies.	
Digital Supply Chain (DSC)	Moderator (SCI to SCC)	Digital products and services, digitalized processes, digital business models; digital collaboration with partners		(Liu et al., 2022; Shahadat et al., 2023; Zhao et al., 2023)
		DSC1	Our company has adopted digital products and services that enhance customer value creation and strengthen digital capabilities.	
		DSC2	Our company has implemented digitally enabled management systems and operational processes in its dailiy business activities.	
		DSC3	Our company has implemented a digital business model across its core business operations.	
		DSC4	Our company operates an integrated digital supply chain platform that connects	

			customers, distributors, and suppliers.	
		DSC5	Digital technologies are consistently utilized in real time for transactions with suppliers and customers.	
Biodiesel Policy (BP)	Moderator (SCC to SCP)	Effectiveness of biodiesel mandates, subsidies, tax incentives, research support, and policy coherence		(Agustina et al., 2023; Israel & Siwandeti, 2024; Usmani et al., 2023; Zheng et al., 2020)
		BP1	The mandatory biodiesel blending policy provides demand certainty for our company's fuel procurement and distribution activities.	
		BP2	Government biodiesel subsidies and fiscal support our company to maintaining cost efficiency in supply chain operations.	
		BP3	Tax incentives and biodiesel price stabilization mechanisms reduce cost fluctuation risks within our fuel supply chain.	
		BP4	Government support for research and technological development of biodiesel infrastructure enhances the reliability and quality of biodiesel supply in our company.	
		BP5	Biodiesel policies covering blending mandates, allocation volumes, subsidies, taxation, and research support are coherently implemented and strengthen our supply chain performance.	
Supply Chain Performance (SCP)	Dependent variable	Cost efficiency; lead time; flexibility; resilience; customer fulfillment; economic viability		(Agustina et al., 2023; Israel & Siwandeti, 2024; Jing & Fan, 2024; Liao et al., 2022; Liu et al., 2022; Luqman et al., 2023; Usmani et al., 2023; Zhao et al., 2023)
		SCP1	Supply chain digitalization enhances inter-organizational collaboration and contributes to lower operating costs.	
		SCP2	Rapid adaptability strengthens our company's ability to respond to market changes and supply chain disruptions, thereby improving operational resilience.	

		SCP3	Our company consistently fulfills customer orders within short lead times and according to agreed delivery schedules.	
		SCP4	Our company consistently meets customer requirements in accordance with specified product standards and specifications.	
		SCP5	The biodiesel policy encourages our company to actively collaborate with supply chain partners to improve forecasting accuracy.	
		SCP6	Our company is able to withstand economic pressures and unexpected costs without disrupting the long-term sustainability of its supply chain.	

RESULTS AND DISCUSSION

Respondent Profile

The respondents are employees and managerial staff of fuel trading companies and contractors operating in the N-PSO sector who are directly involved in supply chain activities and regulatory coordination. 195 respondents out of a total of 204 met the criteria and characteristics required for this study, indicating adequate contextual understanding of supply chain integration, digitalization initiatives, and regulatory impacts. This supports the reliability of the perceptual measurements used in the survey, based on the referenced sampling procedure.

Table 3. Summary of Respondent Profile

Age group	**Frequency**	**Valid (%)**
18–30 years	36	18.5
≥ 30–40 years	96	49.2
≥ 40–50 years	53	27.2
≥ 50–65 years	10	5.1
Total	195	100.0
Education level	**Frequency**	**Valid (%)**
High school or equivalent	13	6.7
Diploma	33	16.9
Bachelor's degree (S1)	130	66.7
Postgraduate (S2/S3)	19	9.7
Total	195	100.0
Work division	**Frequency**	**Valid (%)**
Supply Chain	28	14.4
Procurement/Purchasing	20	10.3
Operation/Production	89	45.6
Logistics/Distribution	31	15.9
Inventory Control/Warehouse	5	2.6
Finance/Tax/Accounting	14	7.2

Legal	3	1.5
Business&Commercial	5	2.6
Total	195	100.0

Source: Primary Data Processed (2026)

Desriptive Statistic

Overall descriptive results indicate that respondents perceive moderate to high levels of supply chain integration, supply chain capability, and supply chain performance. In contrast, perceptions of digital supply chain adoption and biodiesel policy effectiveness show relatively greater dispersion. Based on the descriptive statistics table, all research variables exhibit mean values within the moderate to high range, with relatively moderate standard deviations, indicating consistent respondent perceptions while still capturing inter-firm variability. SCI records the highest mean (4.294) and the lowest standard deviation (0.476), suggesting that internal and external integration practices are relatively standardized across firms in the N-PSO sector, driven by regulatory requirements and operational coordination needs in fuel distribution. SCC and SCP exhibit stable mean values with moderate dispersion, suggesting that most firms perceive their operational capabilities and performance as satisfactory. However, differences remain in flexibility, responsiveness, and operational resilience. In contrast, DSC and BP display relatively higher standard deviations, 0.7085 and 0.6879, despite maintaining moderate mean values. This pattern reflects heterogeneous levels of digital maturity and diverse organizational perceptions of policy effectiveness across firms. While some firms have adopted integrated information systems and digital monitoring tools, others still rely on semi-manual coordination and fragmented systems. Differences in company size, contractual arrangements, and exposure to subsidy mechanisms may also influence how policy effects are perceived across firms.

Table 4. Summary of Descriptive Statistics per Variables

Variables	Items	Mean	Std. Deviation
Supply Chain Integration	SCII1	4.2154	0.6771
	SCII2	4.2	0.7969
	SCII3	4.4	0.6209
	SCSI1	4.2821	0.7089
	SCSI2	4.0513	0.8479
	SCSI3	4.4154	0.6937
	SCCI1	4.2205	0.7582
	SCCI2	4.4103	0.6856
	SCCI3	4.4564	0.6673
	SCI	**4.2946**	**0.476**
Supply Chain Capability	SCC1	3.8769	0.7073
	SCC2	4.5026	0.6124
	SCC3	4.1641	0.7062
	SCC4	4.1487	0.7416
	SCC5	4.1744	0.7394
	SCC	**4.1733**	**0.532**
Digital Supply Chain	DSC1	3.9744	0.7695
	DSC2	4.1436	0.7929
	DSC3	3.8564	0.8555
	DSC4	3.5949	1.033

	DSC5	4.0718	0.8822
	DSC	**3.9282**	**0.7085**
Biodiesel Policy	BP1	4.2103	0.7474
	BP2	3.9487	0.9565
	BP3	3.8667	0.9539
	BP4	4.0564	0.8567
	BP5	4.1744	0.7801
	BP	**4.0513**	**0.6879**
Supply Chain Performance	SCP1	4.3692	0.6865
	SCP2	4.4513	0.6353
	SCP3	4.3538	0.6983
	SCP4	4.4667	0.6281
	SCP5	4.4051	0.6541
	SCP6	4.2718	0.6758
	SCP	**4.3863**	**0.4925**

Source: Primary Data Processed (2026)

Measurement Model Assessment

The measurement model was evaluated to ensure construct reliability and validity before structural hypothesis testing. During the measurement model evaluation, all indicators were initially assessed for reliability and conceptual relevance. No indicators were removed, as all loading values exceeded the recommended threshold of 0.60 and were theoretically aligned with their respective constructs. Convergent validity was assessed using factor loadings and Average Variance Extracted (AVE). AVE values for all constructs exceeded the recommended cut-off of 0.50, indicating that their respective latent constructs explained more than 50% of indicator variance. Specifically, AVE values were above 0.60 for the supply chain integration dimensions, 0.688 for the digital supply chain, and 0.626 for biodiesel policy. Internal consistency reliability was confirmed using Composite Reliability, with all values exceeding the 0.70 threshold, indicating stable and consistent measurement scales.

Table 5. Summary of Validity and Reliability Test Result

Variabel	Item	Factor Loading	AVE	Composite Reliability	Decision
Supply Chain Integration	SCII1	0.768	0.634	0.839	Valid and Reliable
	SCII2	0.814			
	SCII3	0.807			
	SCSI1	0.847	0.620	0.830	
	SCSI2	0.723			
	SCSI3	0.787			
	SCCI1	0.788	0.643	0.844	
	SCCI2	0.830			
	SCCI3	0.786			
Supply Chain Capability	SCC1	0.714	0.573	0.869	Valid and Reliable
	SCC2	0.654			
	SCC3	0.754			
	SCC4	0.827			
	SCC5	0.821			
Digital Supply Chain	DSC1	0.905	0.688	0.916	

ISSN 2776-1266 (print), 2776-1266 (online)

	DSC2	0.825			Valid and Reliable
	DSC3	0.888			
	DSC4	0.635			
	DSC5	0.865			
Biodiesel Policy	BP1	0.734	0.626	0.893	Valid and Reliable
	BP2	0.727			
	BP3	0.772			
	BP4	0.852			
	BP5	0.861			
Supply Chain Performance	SCP1	0.801	0.554	0.881	Valid and Reliable
	SCP2	0.805			
	SCP3	0.721			
	SCP4	0.695			
	SCP5	0.797			
	SCP6	0.631			

Source: Primary Data Processed (2026)

Moreover, discriminant validity was further assessed using the Heterotrait–Monotrait ratio (HTMT) with all values remained below the recommended threshold (0.90), confirming that each construct is empirically distinct. These results strengthen confidence in the robustness and validity of the measurement model and are suitable for subsequent structural model analysis.

Table 6. Summary of Discriminant Validity Test Result

	BP	**DSC**	**SCC**	**SCC_BP**	**SCI**	**SCI_DSC**	**SCP**
BP							
DSC	0,597						
SCC	0,645	0,609					
SCC_BP	0,246	0,196	0,270				
SCI	0,625	0,826	0,888	0,204			
SCI_DSC	0,104	0,271	0,273	0,515	0,337		
SCP	0,671	0,709	0,818	0,250	0,718	0,184	

Source: Primary Data Processed (2026)

Structural Model Assessment

The structural model was evaluated to assess the robustness of causal estimation using multicollinearity diagnostics and an assessment of explanatory power. The Variance Inflation Factor (VIF) values for all predictors and interaction constructs remain below the conservative threshold of 5 in both the Supply Chain Capability and Supply Chain Performance models. indicating the absence of critical multicollinearity. This confirms that the estimated path coefficients are stable. free from redundancy bias. and suitable for subsequent hypothesis testing.

Table 7. Multicollinearity (Inner VIF) Test Result

Predictors	**VIF for SCC**	**VIF for SCP**
SCI	2.074	2.361
SCC		2.480
DSC	1.998	
BP		1.578
SCI_DSC	1.116	
SCC_BP		1.089

ISSN 2776-1266 (print), 2776-1266 (online)

Source: Primary Data Processed (2026)

The model's explanatory power was assessed using the coefficient of determination. The adjusted R^2 for Supply Chain Capability is 0.676 indicates the combination of Supply Chain Integration, Digital Supply Chain, and their joint interaction explains 67.6% of the variance in operational capability, which is classified as strong explanatory power. This finding confirms that integration practices constitute the dominant mechanism shaping capability development in the N-PSO fuel distribution sector. On the contrary, the adjusted R^2 value for Supply Chain Performance is 0.543, indicates a moderate level of explanatory power that suggests, while internal Supply Chain Capabilities and Supply Chain Integration mechanisms are central drivers, additional contextual factors may also influence performance outcomes. Potential omitted variables include market competition intensity, infrastructure readiness, logistics network reliability, and contractual governance mechanisms among supply chain actors in the interactions of Biodiesel Policy. Incorporating these variables in future models may provide a more comprehensive explanation of performance variability in the N-PSO fuel sector.

Table 8. Coefficient of Determination (R-square) Test Result

Endogenous Construct	R Square	R Square Adjusted
SCC	0.681	0.676
SCP	0.553	0.543

Source: Primary Data Processed (2026)

Hypothesis Testing Results

The hypotheses were tested using bootstrapping to obtain path coefficients which represent the direction and strength of relationships between latent constructs, it considered significant if the t-statistic exceeds 1.96 or the p-value is less than 0.05, following recommended procedures for PLS-SEM (Hair et al., 2019). Based on the path coefficient estimation results, most of the structural hypotheses in this study receive strong empirical support, as reflected in positive coefficients, t-statistics above the critical threshold, and p-values below 0.05. Specifically, the relationship between Supply Chain Integration and Supply Chain Performance (H1) shows a positive coefficient of 0.198, with a t-statistic of 2.251 and a p-value of 0.012, indicating that the hypothesis is supported. The effect of Supply Chain Integration on Supply Chain Capability (H2) exhibits the largest coefficient, at 0.381, with a t-statistic of 6.088 and a p-value of 0.000, confirming strong empirical support. These results indicate that higher levels of internal and external integration enhance coordination efficiency, information alignment, and operational reliability in the N-PSO fuel distribution sector.

Furthermore, Supply Chain Capability demonstrates a positive and significant effect on Supply Chain Performance (H3), with a coefficient of 0.339, a t-statistic of 4.225, and a p-value of 0.000. The indirect effect of Supply Chain Integration on Supply Chain Performance through Supply Chain Capability (H4) is also significant, with a coefficient of 0.129, a t-statistic of 3.513, and a p-value of 0.000, confirming the mediating role of capability. These findings indicate that integration primarily improves performance through capability formation rather than through direct structural alignment alone. The direct effect of Supply Chain Integration on Supply Chain Performance (H1), although significant, the coefficient is relatively modest compared with its indirect effect through Supply Chain Capability. Thus, validates that integration alone does not automatically translate into substantial performance gains unless it is internalized into organizational routines and operational capabilities.

In contrast, the interaction effect of Digital Supply Chain on the relationship between Supply Chain Integration and Supply Chain Capability (H5) is not significant, as indicated by a coefficient of 0.000, a t-statistic of 0.014, and a p-value of 0.494. Similarly, Biodiesel Policy does not significantly moderate the relationship between Supply Chain Capability and Supply Chain Performance (H6), as reflected in a coefficient of −0.048, a t-statistic of 1.078, and a p-value of

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0.141. These results indicate that digitalization and regulatory intervention do not materially alter the strength of the model's core causal mechanisms.

Table 9. Hypothesis Testing Result

Hypothesis		Coefficient	t-statistic	p-value	Decision
H1	Supply chain integration has a positive effect on supply chain performance.	0.198	2.251	0.012	Supported
H2	Supply chain integration has a positive effect on supply chain capability.	0.381	6.088	0.000	Supported
H3	Supply chain capability has a positive effect on supply chain performance.	0.339	4.225	0.000	Supported
H4	Supply chain capability positively mediates the effect of supply chain integration to supply chain performance.	0.129	3.513	0.000	Supported
H5	Digital supply chain positively moderates the effect of supply chain integration to supply chain capability.	0.000	0.014	0.494	Not supported
H6	Biodiesel policy positively moderates the effect of supply chain capability towards supply chain performance	-0.048	1.078	0.141	Not supported

Source: Primary Data Processed (2026)

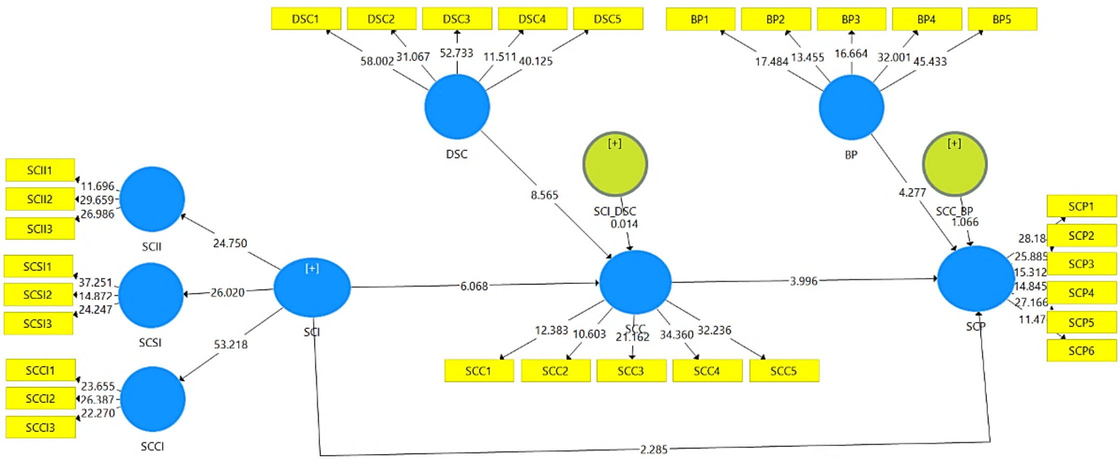

Figure 2. Research Structural Model

Source: SmartPLS SEM diagram

The overall findings of this study construct a coherent explanatory framework in which Supply Chain Integration (SCI) operates as the foundational structural mechanism that enables capability development and ultimately drives performance outcomes. Supply Chain Capability (SCC) functions as the central transformation engine, translating integration into adaptive operational routines, while Supply Chain Performance (SCP) emerges as the realized operational outcome. At the same time, Digital Supply Chain (DSC) and Biodiesel Policy (BP) primarily act as contextual boundary conditions rather than direct performance amplifiers. This configuration highlights the dominance of internal organizational mechanisms in sustaining performance within regulated, infrastructure-intensive energy supply chains.

The Effect of Supply Chain Integration on Supply Chain Performance

Consistent with classical supply chain management theory, Supply Chain Integration (SCI) has long been recognized as a structural driver of performance, as it enables synchronized material flows, coordinated information exchange, and aligned decision-making across internal functions and external partners (Chopra & Meindl, 2021). Empirical evidence across manufacturing, logistics, and energy distribution sectors consistently demonstrates that integration improves delivery reliability, cost efficiency, and operational stability by reducing coordination friction and process variability (Jing & Fan, 2024; Khanuja & Jain, 2022; Liao et al., 2022; Phan et al., 2020).

The empirical findings of this study confirm that SCI has a positive and significant effect on Supply Chain Performance (SCP), indicating that higher levels of internal, supplier, and customer integration enhance operational reliability, distribution efficiency, and service responsiveness. In the Indonesian N-PSO fuel sector which are characterized by regulatory constraints, quality compliance requirements, and volatile biodiesel supply dynamics. Thus, integration strengthens cross-functional alignment, improves demand visibility, and supports supply stability, thereby contributing to more consistent execution performance (Agustina et al., 2023; Ardiansah & Pujawan, 2024). However, the direct contribution of SCI explains only part of the performance variance, suggesting that integration operates not merely as a coordination mechanism but as a strategic infrastructure that enables deeper organizational transformation. From a managerial perspective, this implies that integration should be leveraged as a platform for strengthening adaptive capabilities and operational learning, particularly in policy-driven and infrastructure-constrained environments where performance stability depends on the organization's ability to translate structural coordination into sustained execution capability.

The Effect of Supply Chain Integration on Supply Chain Capability

From a dynamic capability perspective, Supply Chain Integration (SCI) functions not merely as a structural alignment mechanism but as a platform for capability development. Integration provides the organizational architecture through which firms recombine resources, institutionalize learning routines, and embed cross-functional coordination into operational practices (Juan et al., 2022). Prior studies consistently show that integrated workflows, shared performance metrics, and collaborative planning accelerate the development of flexibility, agility, visibility, and resilience capabilities (Liao et al., 2022; Luqman et al., 2023; Zhao et al., 2023). The empirical findings of this study confirm that SCI exerts a stronger influence on Supply Chain Capability (SCC) than on Supply Chain Performance (SCP) directly.

Effective integration enables the formation of adaptive operational capacities, such as distribution coordination, risk management, and responsive logistics planning, which are essential for managing market dynamics and regulatory pressures (Anwar et al., 2025; Irfan et al., 2022). In the biodiesel supply chain, characterized by feedstock price volatility, infrastructure constraints, and policy shifts, these capabilities play a critical role in maintaining operational continuity and stability (Ardiansah & Pujawan, 2024). From a managerial standpoint, this implies that integration should be leveraged as a capability-building platform rather than solely as a coordination mechanism. Organizations that embed integration into routines, decision-making processes, and learning systems are better positioned to develop adaptive competencies and sustain operational performance under uncertainty. Thus, SCI becomes a primary antecedent of long-term capability development and organizational resilience in complex and policy-driven supply chain environments.

The Effect of Supply Chain Capability on Supply Chain Performance

Supply Chain Capability (SCC) demonstrates a direct and substantial effect on Supply Chain Performance (SCP), confirming that performance sustainability is primarily capability-driven rather than structurally determined. From a dynamic capability perspective, organizational performance depends on the ability to translate integration into adaptive operational competencies such as flexibility, responsiveness, coordination efficiency, and risk mitigation (Juan et al., 2022; Luqman et al., 2023). Empirical evidence from energy and logistics sectors similarly shows that resilient capabilities stabilize operational performance under supply volatility and regulatory pressure (Agustina et al., 2023; Romadhona et al., 2024).

The findings indicate that performance improvements in the N-PSO fuel sector are not solely shaped by integration structures but by how effectively organizations internalize integration into operational routines and capability development. In environments characterized by biodiesel policy pressure, feedstock price fluctuations, and infrastructure constraints, capabilities such as adaptive logistics planning, inventory responsiveness, and risk-handling mechanisms become critical for maintaining supply continuity and efficiency. Managerially, this underscores the need to prioritize capability development through cross-functional learning, flexible logistics design, and coordinated risk management rather than relying solely on structural coordination improvements. These results reinforce prior research that positions SCC as a central determinant of operational resilience and sustained performance in complex and uncertainty-intensive supply chain environments (Liao et al., 2022; Agustina et al., 2023).

The Mediating Role of Supply Chain Capability

The mediating role of Supply Chain Capability (SCC) clarifies the causal mechanism through which Supply Chain Integration (SCI) translates into Supply Chain Performance (SCP). Integration enhances performance primarily by strengthening organizational capability rather than acting as a direct linear driver, supporting process-based and dynamic capability perspectives that managerial practices generate value only when internalized into routines, skills, and adaptive decision-making mechanisms (Khanuja & Jain, 2022; Liao et al., 2022). Without sufficient capability maturity, integration investments may improve coordination efficiency but fail to produce meaningful performance resilience, particularly in regulated supply chains such as the N-PSO fuel sector (Asamoah et al., 2021; Lin & Fan, 2024).

Empirically, SCC significantly mediates the SCI–SCP relationship, indicating that integration functions as a structural coordination mechanism while capability operates as a transformation mechanism that converts integration into operational value. In policy-driven and infrastructure-constrained environments, this mediation becomes more pronounced because performance depends on adaptive execution rather than structural flexibility alone. Thus, the effectiveness of integration is contingent upon the organization's ability to translate coordinated processes into adaptive operational competencies. This finding aligns with prior studies highlighting capability as the primary pathway through which integration enhances performance (Liao et al., 2022). SCC, in turn, acts as the operational engine of performance realization, as capabilities such as flexibility, responsiveness, coordination efficiency, and risk mitigation enable organizations to maintain reliability and cost efficiency under environmental turbulence (Juan et al., 2022; Luqman et al., 2023). Evidence from energy and logistics sectors further confirms that resilient and adaptive capabilities stabilize distribution performance under supply volatility and regulatory pressure, emphasizing that sustainable performance depends on continuous sensing, adaptation, and reconfiguration of operational processes (Agustina et al., 2023; Romadhona et al., 2024).

The Moderating Role of Digital Supply Chain

The findings indicate that Digital Supply Chain (DSC) does not significantly strengthen the transformation of Supply Chain Integration (SCI) into Supply Chain Capability (SCC), challenging the common assumption that digitalization automatically accelerates capability development. While prior studies emphasize the role of digital technologies in enhancing visibility, analytics capability, and real-time coordination (Cui et al., 2024; Shahadat et al., 2023; Amelia Asifah et al., 2025), the results suggest that these benefits materialize only when supported by digital maturity, strong data governance, and organizational readiness (Putra et al., 2024). From a dynamic capability perspective, digitalization contributes to capability formation only when

ISSN 2776-1266 (print), 2776-1266 (online)

embedded within routines, learning mechanisms, and cross-functional decision-making processes (Chopra & Meindl, 2021).

In the N-PSO context, which more characterized by regulatory constraints and uneven digital adoption, capability formation remains primarily driven by structural and relational mechanisms such as coordination intensity, logistics flexibility, and policy responsiveness. Digital technologies therefore function more as supporting infrastructure than as primary drivers of capability development. Their strategic value becomes evident when organizations are able to integrate digital tools into operational processes and decision-making systems. This finding refines digital supply chain and dynamic capability literature by positioning digitalization not as a universal capability accelerator but as a contingent, maturity-dependent enabler. In regulated and infrastructure-constrained environments, digital investments generate performance value mainly during the capability exploitation stage rather than early capability formation, highlighting the importance of contextual readiness in determining the effectiveness of digital transformation initiatives (Zhao et al., 2023).

The Moderating Role of Biodiesel Policy

Similarly, the findings show that Biodiesel Policy (BP) does not significantly moderate the relationship between Supply Chain Capability (SCC) and Supply Chain Performance (SCP), indicating that macro-level policy intervention does not automatically strengthen micro-level capability–performance linkages. Consistent with institutional theory, biodiesel policy primarily functions as a boundary condition shaping operational constraints rather than as a direct performance leverage mechanism (Israel & Siwandeti, 2024). Its effectiveness depends on incentive design, implementation mechanisms, and integration into organizational strategy rather than policy presence alone (Zheng et al., 2020). In compliance-oriented environments such as the N-PSO fuel sector, homogeneous policy implementation reduces opportunities for strategic differentiation, limiting firms' ability to translate superior capabilities into relative performance advantages (Agustina et al., 2023). The influence of policy at the firm level therefore depends on regulatory stability, long-term consistency, and alignment with operational practices (Halimatussadiah et al., 2021; Husada et al., 2023). Under such conditions, operational performance remains primarily driven by internal organizational capabilities rather than regulatory intervention. This finding contributes to supply chain and institutional research by positioning biodiesel policy as an institutional stabilizer and systemic risk governance mechanism rather than a direct performance amplifier (Ardiansah & Pujawan, 2024). It highlights that policy effectiveness in regulated energy supply chains is contingent upon organizational readiness and strategic alignment, reaffirming the central role of internal capabilities as the dominant drivers of sustained operational performance. Overall, the study contributes to theory in two ways. First, it confirms the established role of integration and capability as primary drivers of supply chain performance. Second, it extends existing models by demonstrating that in a highly regulated renewable energy context, digitalization and policy do not uniformly amplify performance mechanisms. Instead, their effectiveness depends on organizational readiness, institutional alignment, and maturity infrastructure. This finding refines dynamic capability and supply chain management theory by emphasizing the contextual conditions under which performance benefits materialize.

CONCLUSION

This study concludes that supply chain performance in the Indonesian N-PSO fuel sector is primarily determined by how effectively firms integrate supply chain activities and translate that integration into adaptive operational capabilities. Supply Chain Integration improves performance both directly and indirectly through Supply Chain Capability, confirming capability as the key mechanism linking structural coordination to reliable and resilient execution. Digital Supply Chain and Biodiesel Policy do not consistently strengthen this relationship; instead, their performance value depends on organizational readiness, implementation depth, and institutional maturity. These findings reinforce that sustainable performance in regulated energy supply chains is fundamentally capability-driven and relies on the internalization of integration into learning routines, governance structures, and operational competencies rather than on technological adoption or policy presence alone.

ACKNOWLEDGMENT

Managerially, firms should prioritize strengthening cross-functional and inter-organizational integration to improve process alignment, information transparency, and collaborative decision-making, while deliberately building capabilities in flexibility, responsiveness, coordination efficiency, and risk mitigation. Digital investments need to be embedded in core operational routines and decision-support systems, not treated merely as tools for transactional efficiency. Policymakers should complement biodiesel blending mandates with institutional support that enables integration and capability development (e.g., shared infrastructure incentives, interoperable data platforms, and structured capability-building programs). Future research could broaden sectoral coverage, employ probability or mixed-methods designs, and use longitudinal data to capture the evolution of capabilities under higher biodiesel blending targets and ongoing digital transformation, including additional constructs such as supply chain resilience and risk management capability.

ACKNOWLEDGMENT

The authors did not receive any specific grants from public funding agencies, commercial, or non-profit sectors for this research. The authors would like to thank all participating non-public service obligation fuel companies and professionals who provided valuable data and insights for this study.

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