Assessing the Impact of LNG Fuel use in Logistics on Operational Efficiency and Economics in the Vietnamese Agricultural Export Supply Chain

Ha Minh Hieu, Ho Thi Trang Nhung

Department of Aviation Economics, Vietnam Aviation Academy.

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SUMMARY

This study aims to assess the impact of applying liquefied natural gas (LNG) as a green energy solution on logistics operations and the efficiency of Vietnam's agricultural export supply chain. Using a qualitative and quantitative approach with a PLS-SEM model, the research results confirm that supportive policies positively promote the adoption of LNG in green supply chains; the adaptability of businesses; and the readiness for technological innovation. Interestingly, the study highlights the moderating role of supportive policies in relation to the level of LNG usage in logistics, which most strongly impacts both economic efficiency and logistics operations. To transform supportive policies into a competitive advantage from LNG adoption, businesses need to view this as an opportunity to invest heavily in digital transformation, strengthen the institutional framework, focus on policy, create a green and smart logistics ecosystem, develop infrastructure, and promote LNG use, ultimately making LNG a pillar for the sustainable development of the agricultural supply chain.

Keywords : logistics performance, supply chain economic efficiency, green logistics, LNG fuel, agricultural supply chain.

INTRODUCTION

The logistics sector in Vietnam plays a crucial role in supporting agricultural exports, with the core objectives of reducing costs, improving operational efficiency, and increasing export value (Ngo et al., 2019; Pham, 2020). However, the sector still faces significant challenges such as a shortage of high-quality human resources and limitations in integrating and investing in modern technology (Nguyen, 2020; Xu et al., 2023). At the macro level, logistics is a key driver of globalization and international trade, facilitating efficient goods transportation (Pörtner, 2023; Varma & Shah, 2021). Enhanced logistics capacity is linked to positive economic growth, increased productivity, and national economic development (Bugarčić et al., 2024; Goel et al., 2021).

To address the pressures of cost, operational efficiency, and emission reduction targets in logistics, research into the potential and effectiveness of using LNG in agricultural supply chains is a direction that offers practical application value. LNG (Liquefied Natural Gas) is natural gas, primarily methane, liquefied at approximately 162°C (Anaraki & Rahimpour, 2024). It is considered a clean fuel solution due to its ability to significantly reduce greenhouse gas emissions as well as harmful emissions such as NOx, SOx, and fine particulate matter (Anaraki & Rahimpour, 2024; Sari et al., 2023). With a higher energy density than Compressed Natural Gas (CNG), LNG is particularly suitable for heavy-duty and long-distance transport vehicles (Arteconi & Polonara, 2013). The use of LNG not only helps reduce fuel costs compared to diesel, but also diversifies the supply source, reducing dependence on imported petroleum (Osorio-Tejada et al., 2017). Due to these outstanding advantages, LNG has been widely applied in heavy transport and shipping in many areas with strict emission control regulations (Banaszkiewicz et al., 2020; Orysiak & Shuper, 2025). Many countries, including Vietnam, are developing frameworks to promote the use of this clean fuel. The adoption of LNG is expected to have a positive impact on logistics efficiency and the greening of Vietnam's agricultural supply chain.

Numerous studies have employed diverse theories and methodologies to assess the impact of LNG in logistics, including integrated risk models based on energy theory (Wu et al., 2021), sustainable lifecycle assessments from environmental, economic, and social perspectives (Al-Kuwari et al., 2025; Al-Yafei et al., 2022), and optimization of LNG distribution in multimodal transport (Zhang et al., 2024). However, significant gaps remain. Specifically, current studies primarily focus on technical, operational, and environmental aspects, but fail to clarify the role of organizational capacity, institutional capacity, supporting policies, and the energy transition behavior of enterprises in applying LNG to green supply chains. Furthermore, there is a lack of integrated analyses of the relationship between internal capacity and the adaptability of enterprises in the context of green logistics.

OVERVIEW OF THE STUDY

Underlying Theories

Resource Orchestration Theory (ROT) analyzes the role of managers in transforming resources into competitive capabilities (Sirmon et al., 2012). ROT emphasizes that the dynamic capabilities of an enterprise depend not only on available resources but also on the strategic coordination abilities of managers. In the agricultural supply chain, the use of LNG is considered a strategic resource. The core activities of ROT include: (i) structuring, identifying, investing in, and organizing resources; (ii) combining and integrating resources to form operational capabilities; (iii) exploiting and utilizing capabilities to create value, improve efficiency, and maintain competitive advantage. In this context, ROT is applied to analyze the LNG infrastructure structure (including refueling stations, vehicles, and storage systems), thereby integrating LNG into the operational process. The goal is to develop green logistics capabilities, improve operational efficiency, reduce emissions, and enhance competitiveness. Simultaneously, ROT clarifies the crucial role of managers in investment decision-making, technology selection, and cost coordination related to LNG applications.

Green Supply Chain Theory (GrSCM), defined as the integration of environmental thinking into all supply chain activities, from design to product lifecycle management (Srivastava, 2007), is used to assess the impact of green strategies on logistics and economic efficiency. In the context of Vietnamese agricultural businesses facing pressure from international standards and sustainable development requirements, transitioning to green logistics through LNG application is considered a strategic direction to: (i) Optimize transportation, reduce waste, and increase energy efficiency; (ii) Reduce fuel costs, waste treatment costs, and enhance brand image.

Dynamic Capabilities (DC) theory refers to the ability to integrate, build, and restructure internal and external capabilities to cope with a rapidly changing environment (Teece et al., 1997), providing a strategic basis for analyzing a company's responsiveness to technological and environmental changes. LNG deployment is not merely a technical decision but also an innovation strategy, requiring the capacity to restructure processes, integrate technology, and coordinate resources. DC emphasizes: (i) a willingness to innovate and adopt new technologies determines operational efficiency and competitiveness; (ii) the ability to restructure and coordinate flexibly to adapt to market fluctuations, policies, and technical requirements; and (iii) organizational capacity towards sustainable development forms the foundation for long-term economic, environmental, and social effectiveness. In this study, DC is applied to analyze how Vietnamese agricultural businesses adapt to LNG in logistics, specifically through adjusting operational processes, integrating technology, and maintaining the economic efficiency of the supply chain.

Institutional Theory (IT) analyzes the influence of external institutional factors on organizational behavior (Scott, 2008). According to Dimaggio & Powell (1983), it consists of three pillars: (i) Legal regulations; (ii) Social norms; and (iii) Cultural perceptions. This theory provides a basis for assessing the impact of the external environment on the decision to deploy LNG. Specifically, legal regulations create mandatory pressure for businesses to comply with and use LNG. Social norms create pressure from the community, encouraging green logistics. Finally, cultural perceptions shape the logic of action, promoting the selection of LNG that aligns with general development trends.

Research Model

Impact of LNG Resources on the Green Supply Chain.

LNG resources are understood as the level of LNG usage, supply, and investment and operating costs of LNG infrastructure. According to the ROT theoretical framework, the impact of LNG stems not only from the fuel itself, but also from how businesses organize, combine, and exploit related resources to create value. This view is strongly reinforced by recent empirical studies. Specifically, Mikolajková-Alifov et al. (2019) argued that stable supply and suitable infrastructure help reduce costs and increase flexibility in the supply chain. Similarly, research by Asha et al. (2024) confirms that integrating clean fuels such as CNG/LNG in optimal supply network combinations can simultaneously reduce costs and emissions. While Qi et al. (2025) demonstrated that systematic investment in a complete LNG chain, including liquefaction, regasification, storage, and carbon capture technology, yields superior economic and environmental benefits, these findings consistently demonstrate that the level of LNG utilization, infrastructure investment, and the stability of LNG cost/supply are key factors determining the greening potential of the supply chain.

H1a: The level of LNG utilization has a positive impact on the greening potential of the agricultural export supply chain.

H1b: LNG infrastructure has a positive impact on the greening potential of the agricultural export supply chain.

H1c: LNG cost and supply have a positive impact on the greening potential of the agricultural export supply chain.

The mediating role of green supply chains in logistics operations and supply chain efficiency.

Recent studies have highlighted the role of green supply chains as a crucial intermediary mechanism. Specifically, Emon & Khan (2025) indicated that environmentally friendly transport, reverse logistics, and sustainable production help link energy innovations with operational efficiency and supply chain efficiency. Following that research, Sabaghieh Yazd et al. (2025) demonstrated that integrating recycling strategies into a two-channel production-distribution network can simultaneously significantly reduce emissions and optimize logistics operating costs. In this context, the impact of LNG becomes clear when applied within a GrSCM system. LNG offers initial benefits (such as reduced emissions and energy costs), thereby enabling businesses to more effectively implement green practices in their supply chains. Activities such as green transport and reverse logistics act as intermediaries, translating the benefits of LNG into concrete operational outcomes. As a result, businesses can optimize logistics operations, reduce production losses during transportation, increase vehicle utilization efficiency, thereby simultaneously improving both the logistics efficiency and economic efficiency of the agricultural export supply chain.

H2a: The green supply chain acts as an intermediary in transforming the impact of LNG supply into the logistics performance of businesses.

H2b: The green supply chain acts as an intermediary in transforming the impact of LNG supply into the economic efficiency of the agricultural export supply chain.

The Intermediary Role of Adaptability in Logistics Performance.

The use of LNG is not just an energy choice but also requires businesses to restructure their entire operations, from investing in vehicles and adjusting transportation schedules to integrating refueling infrastructure. According to Teece, Pisano & Shuen (1997), these changes force businesses to enhance their learning, innovation, and process reconfiguration capabilities, which are core components of dynamic capability. Practical studies also emphasize the importance of continuous improvement, organizational learning, and the development and maintenance of flexibility, which are fundamental to business adaptability (Alfaqiyah et al., 2025; Kara et al., 2024; Patrucco et al., 2025). The adoption of LNG creates both pressure and opportunity, prompting businesses to recognize, deploy, and restructure resources flexibly. This process enhances business adaptability and

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improves logistics performance. Thus, adaptability plays a mediating role in the relationship between LNG adoption and logistics efficiency.

H3b: The adaptability and flexibility of businesses mediate the relationship between LNG usage levels and logistics performance.

The Mediating Role of Technology and Innovation Readiness in Supply Chain Economic Efficiency.

Technology and innovation readiness reflects a business's ability to adopt, implement, and operate new solutions, including transitioning to clean energy like LNG and integrating digital transformation tools. The use of LNG is not simply a change in energy source but also creates pressure and opportunities for businesses to improve their operational processes, from investing in vehicles to integrating refueling infrastructure. These changes force businesses to enhance their capacity to adopt and apply technology. Process structuring and coordination of activities are core elements of innovation capability (Li et al., 2025; Pi & Chang, 2024). Empirical studies demonstrate that technological and innovation readiness is a mediating mechanism, enabling businesses to effectively utilize LNG to enhance process coordination and optimize costs, thereby improving the economic efficiency of the supply chain.

H3a: Technological and innovation readiness mediates the relationship between LNG utilization levels and supply chain economic efficiency.

The role of supporting policies in regulating the relationship between LNG utilization levels and green supply chains, adaptability, and technological and innovation readiness.

Supporting policies are understood as external institutional factors, including measures by the State, international organizations, or foreign partners. To facilitate businesses' access to and deployment of new technologies, policies include financial incentives, LNG infrastructure support, and encouragement of green innovation. According to IT theory, supportive policies act as regulatory mechanisms, indirectly transforming LNG use into positive outcomes in the supply chain through three main mechanisms. Firstly, through financial incentives and LNG infrastructure support, policies help reduce barriers to clean energy deployment, encouraging businesses to adopt green supply chain practices (Burki, 2018; Chen et al., 2024). Secondly, measures to encourage R&D and green innovation promote investment in research and development of technology, thereby increasing innovation capacity and improving economic and environmental efficiency (Beigizadeh et al., 2022; Delgoshaei et al., 2022). Thirdly, ensuring transparency and policy stability facilitates businesses in proactively restructuring processes and enhancing the adaptability of the supply chain (Al Mamun et al., 2025; Jum’a et al., 2025). Through these three mechanisms, along with IT theory, policy support acts as a bridge, regulating the relationship between LNG usage and intermediate outcomes, thereby indirectly improving the operational, economic, and environmental efficiency of the supply chain.

H4a: Policy support plays a role in regulating the relationship between the level of LNG usage and the greening capacity of the supply chain.

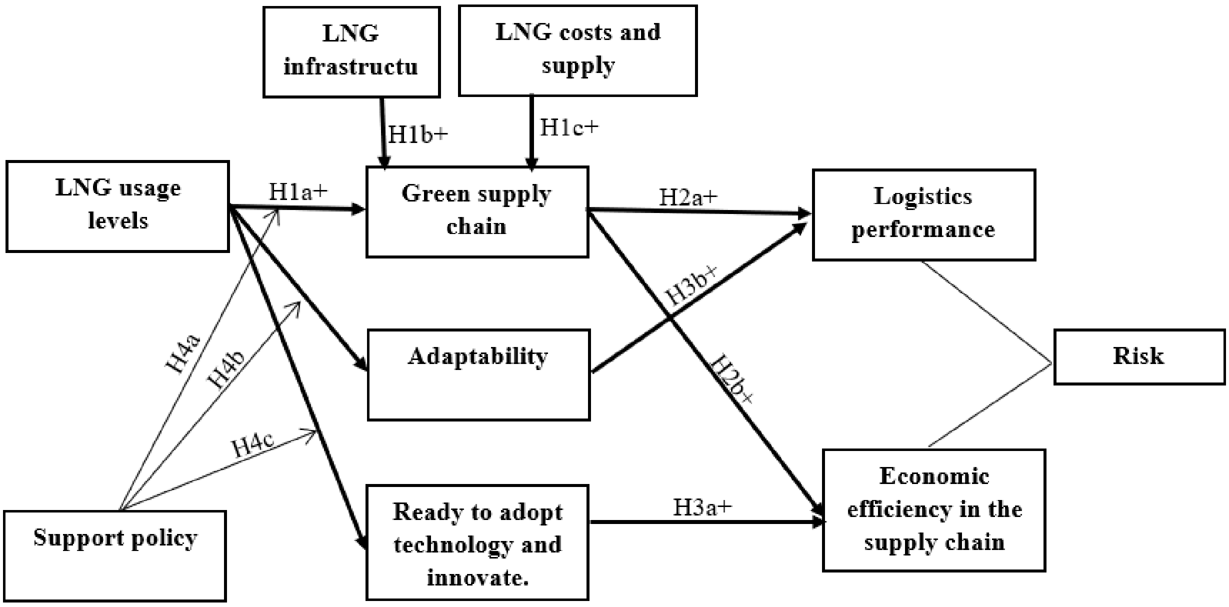
H4b: Policy support plays a role in regulating the relationship between the level of LNG usage and the technological innovation capacity of businesses.

H4c: Policy support plays a role in regulating the relationship between the level of LNG usage and the adaptability and flexibility of businesses.

Ensuring Model Stability Through Risk Control Variables.

Logistical risk is a significant exogenous factor in supply chain management, especially for agricultural supply chains which are sensitive and prone to disruption. Recognizing that logistical risk indirectly affects operational efficiency and economic performance, this study includes it as a control variable. The aim is to eliminate unwanted exogenous influences, thereby ensuring objectivity and stability in evaluating the key relationships in the model.

Proposed research model



Source : Author's analysis

RESEARCH METHODOLOGY

To ensure practicality and reliability, the study adopted a mixed research methodology in model development. In the qualitative phase, the author conducted in-depth interviews (with four experts: a logistics director, an official from the Department of Industry and Trade, a PV GAS specialist, and a university lecturer with experience in agricultural logistics and clean energy). The purpose of this phase was to adjust the theoretical model and refine the questionnaire to suit the context of LNG application in Vietnam. Next, the study used quantitative methods to test the hypotheses developed. The collected data were analyzed using Partial Least Squares (PLS-SEM), with testing steps including evaluating the measurement model and structural model to determine the reliability, convergence, discriminant, and overall fit of the research model.

Sampling

Research data was collected through an online Google Form questionnaire. The study used a convenient sampling method and was conducted from February 2024 to September 2025. A total of 422 responses were received; after removing 67 invalid responses, 355 valid responses remained. The survey subjects included individuals working in organizations related to logistics and agricultural exports, specifically: 30.4% from logistics businesses (transportation, cold storage, distribution centers), 32.1% from agricultural export businesses (processing, trading), 24.5% from agricultural cooperatives (medium and large-scale production), and 13.0% from policy management agencies (related to energy and logistics). The questionnaire consisted of three parts: subject screening, measurement of variables in the theoretical model, and demographic information.

Scale

Survey participants were asked to rate their level of agreement with each statement using a 5-point Likert scale, with values ranging from 1 = “strongly disagree” to 5 = “strongly agree”. The use of this scale helps ensure quantification and statistical analyzeability in subsequent model testing steps.

LNG resources comprise three components: application level, infrastructure, and supply costs. The LNG application level is measured through five items reflecting LNG deployment in inbound transport, inland transport, cold storage, final delivery, and the use of LNG as a primary fuel (Bittante et al., 2018; Budiyanto et al., 2023; Hakan & Betül, 2020; Wang et al., 2018). LNG infrastructure comprises six items, assessing accessibility to refueling stations, storage capacity, distribution network connectivity, port handling capacity, technological equipment, and support from infrastructure planning (Christiansen et al., 2007; Kumar et al., 2011). LNG costs and supply comprise six items, reflecting stability, predictability, price volatility, transportation costs, contract bargaining power, and logistics responsiveness (Bittante et al., 2018; Jokinen et al., 2015).

The green supply chain scale is measured across two groups: the environmental GSCM and the efficiency GSCM. The environmental group includes four items: emission reduction, compliance with international standards, environmentally friendly infrastructure design, and LNG cost control (Assumpção et al., 2024; Ramandi et al., 2025). The efficiency group comprises three items: operational improvement, economic contribution, and green chain development strategy (Das, 2017; Olugu et al., 2011).

Organizational capacity is measured through adaptability, flexibility, and readiness for innovation. The adaptability scale includes seven items: strategic adjustment, LNG technology deployment, organizational structure, process restructuring, human resource capacity, flexibility maintenance policies, and economic efficiency (Aksu & Başaran, 2025; Al Mamun et al., 2025; Hoyt et al., 2007). The innovation readiness scale includes six items, focusing on new technology deployment, technical and human resource capacity, internal policy support, innovation culture, technology updates, and economic impact (Liu et al., 2024; Olugu et al., 2011; Rauniar et al., 2024). The policy support scale is based on institutional theory and comprises seven items reflecting the regulatory role of the state, the degree of facilitation, promotion of green standards, support for investment and technological innovation, capacity building, clarity, policy linkage, and encouragement of technological innovation (Colicchia et al., 2013; Zhu et al., 2008, 2013).

Logistical risks are measured through six items, focusing on LNG price volatility, supply instability, policy changes, investment risks, environmental impacts, and disruptions to the logistics chain affecting GSCM and technological innovation (Olugu et al., 2011; Pais Montes et al., 2019; Townsend, 2022).

RESULTS AND DISCUSSION

Measurement Model

The study performed a reliability and validity analysis of the scale, focusing on the factor loading coefficients, Cronbach's Alpha, composite reliability (CR), and mean variance extracted (AVE). The results showed that all observed variables met the required reliability threshold, with Cronbach's Alpha ranging from 0.839 to 0.879 and CR exceeding 0.6 (Hair et al., 2010), reflecting high internal consistency and good composite reliability of the scale. Regarding convergence validity, the external loading coefficients and AVE of each factor were greater than 0.5, meeting the convergence assessment criteria as recommended by Hair et al. (2010). In particular, the scale achieved discriminant validity according to both the Fornell-Larker criteria and was reinforced by the HTMT ratio (Henseler et al., 2015), confirming the ability to clearly distinguish between concepts. Overall, the measurement model in this study fully meets the requirements for reliability, convergent validity, and discriminant validity, providing a solid foundation for further analyses.

Table 1: Reliability and Validity

Measuring instrument	Factor loading coefficients	Cronbach's Alpha	Composite Reliability	Mean extracted variance (AVE)
LNGU	0.786	0.839	0.886	0.608
LNGINF	0.775	0.868	0.901	0.602
LNGC	0.766	0.859	0.895	0.587
GSCM	0.759	0.878	0.905	0.577

DC	0.761	0.879	0.906	0.580
DCTECH	0.777	0.869	0.901	0.604
LOG	0.753	0.847	0.887	0.567
ECON	0.750	0.845	0.886	0.525
INST	0.723	0.849	0.885	0.525
RISK	0.771	0.864	0.898	0.596

Source : Author's own calculations

Table 2 : Discriminant Validity Test

	DC	**DCTEH**	**ECON**	**GSCM**	**INST**	**LNGC**	**LNGINF**	**LNGU**	**LOG**	**RISK**
DC	**0.761**									
DCTECH	0.625	**0.777**								
ECON	0.650	0.631	**0.751**							
GSCM	0.584	0.610	0.593	**0.760**						
INST	-0.522	-0.549	-0.519	-0.551	**0.724**					
LNGC	0.597	0.582	0.596	0.610	-0.516	**0.766**				
LNGINF	0.627	0.594	0.613	0.645	-0.530	0.601	**0.776**			
LNGU	0.581	0.577	0.590	0.588	-0.519	0.569	0.608	**0.780**		
LOG	0.616	0.610	0.604	0.608	-0.482	0.594	0.620	0.592	**0.753**	
RISK	-0.614	-0.639	-0.632	-0.604	0.550	-0.622	-0.628	-0.593	-0.582	**0.772**

Source : Author's own calculations

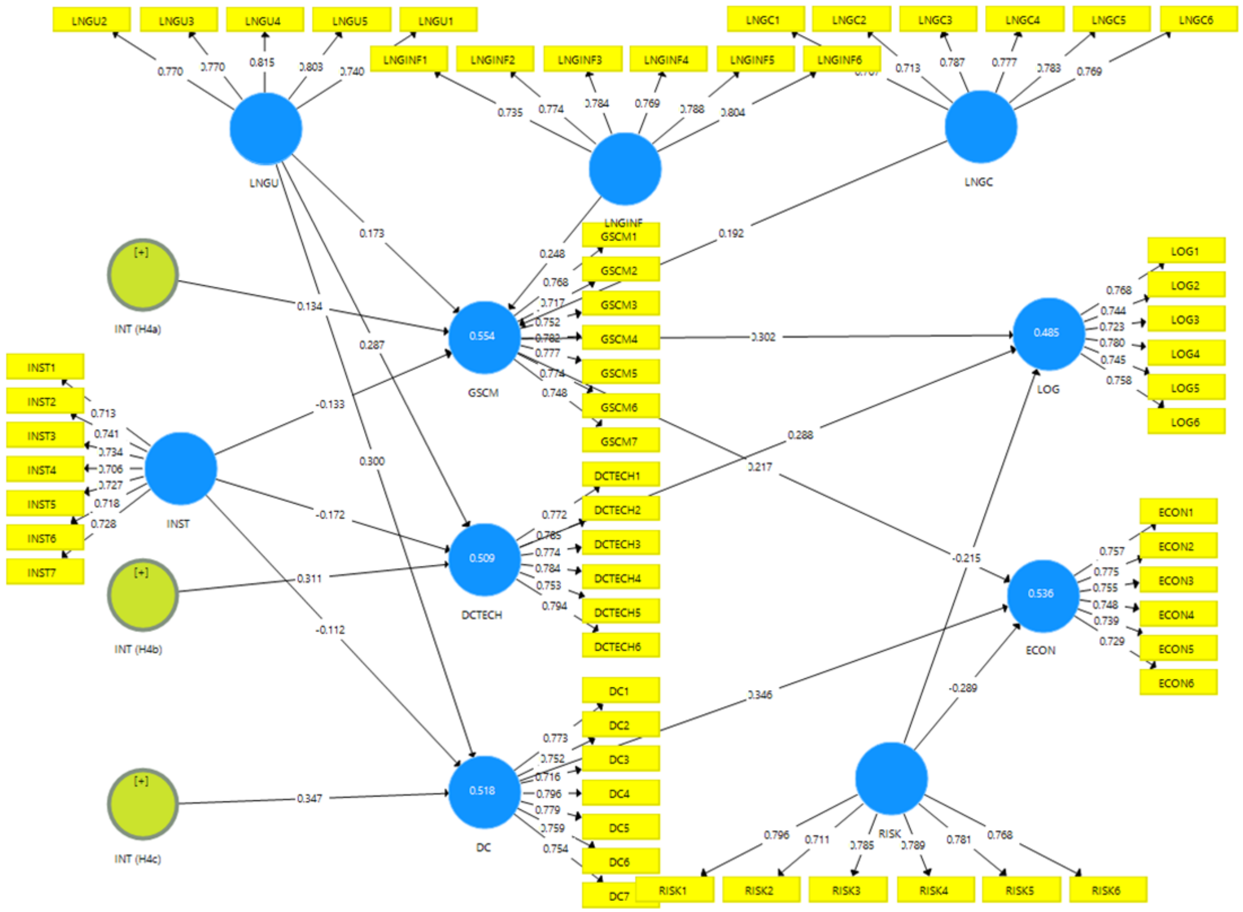
Adjusted R-Square Test

This test assesses the model's generalizability. The adjusted R-Square values are all within the range of 0.480 – 0.55, achieving a medium to fairly good explanatory power as recommended by Hair et al., 2010. Specifically, GSCM has the highest explanatory power (Adjusted R2 = 0.548), followed by ECON with 0.532. Meanwhile, LOG has the lowest explanatory power at 0.480. This indicates that the independent and mediating variables in the model explain between 48.0% and 54.8% of the variation in the related dependent and mediating variables.

Hypothesis Testing, Indirect Relationships, and Total Indirect Effects.

Hypothesis testing analysis revealed that most relationships were statistically significant (p-value < 0.05), except for two hypotheses which did not reach the significance threshold. All f2 coefficients were greater than 0.02, confirming the significant influence between the variables. The study also focused on analyzing the indirect and total indirect impacts of supporting policy factors (INST) and LNG resources (LNGC, LNGINF, LNGU) on economic efficiency (ECON) and logistics efficiency (LOG). These impacts were mainly transmitted through mediating variables such as adaptability (DC), green supply chain (GSCM), and digital technology readiness (DCTECH). The results showed that, at the 5% significance level, most indirect relationships were statistically significant, highlighting the role of mediating variables in the model.

Figure 2: Model estimation results



Source : Author's calculations using Smart PLS4

DISCUSSION OF RESEARCH RESULTS

The study confirms that the fundamental factors of green supply chain management (GSCM), flexibility capacity (DC), and technological readiness (DCTECH) have a direct and strong impact ($p < 0.001$) on economic efficiency (ECON) and logistics performance (LOG). In particular, the coefficients DC → ECON ($\beta = 0.346$) and GSCM → LOG ($\beta = 0.302$) stand out, indicating that green adaptation and governance are the most direct levers for improving business performance. This is consistent with and expands on the research of Emon & Khan (2025) and Sabaghieh Yazd et al. (2025), clarifying the theory of Teece et al. (1997), proving that GSCM and DC are indeed "intermediate mechanisms" that transform benefits from LNG into results.

Furthermore, the variables LNGC, LNGINF, and LNGU significantly influence DC, DCTECH, GSCM, and indirectly ECON and LOG, reinforcing the views of previous studies on the use of clean energy in transportation, economics, and manufacturing activities (Arteconi & Polonara, 2013; Orysiak & Shuper, 2025; Pais Montes et al., 2019). The results of the mediating analysis show that the impact chains INT → DC → ECON, INT → DCTECH → LOG, and LNGU → GSCM → ECON/LOG are all statistically significant, confirming that digital transformation capacity and the application of green supply chains are effective bridges for transforming the efficiency of logistics activities and the national economy. In particular, LNGU → ECON ($\beta = 0.141$) and LNGU → LOG ($\beta = 0.135$) are the two strongest relationships, highlighting the crucial role of using clean energy, specifically LNG, in the process of global integration, towards a sustainable future that will become a strong competitive advantage in Vietnam. These findings highlight solid evidence that the trio of intermediary capabilities DC, DCTECH, and GSCM truly act as effective "bridges." They are the central mechanism for transforming potential benefits from supportive policies and clean fuel sources into stable operational efficiency and sustainable economic benefits for Vietnamese logistics businesses.

CONCLUSION AND MANAGEMENT IMPLICATIONS

First, businesses need to prioritize the use of LNG in logistics operations, coupled with energy risk management, and implement planned investments with regular monitoring. LNG testing should begin with internal trucks, inter-port transport, and warehouses, accompanied by periodic reports to measure costs, economic efficiency, and emissions before and after implementation, in order to optimize economic and environmental benefits. Simultaneously, energy risk management should be emphasized through monitoring LNG price fluctuations, updating energy policies, signing long-term contracts with suppliers, and establishing contingency funds to ensure stable supply and long-term cost control. To improve operational efficiency, businesses should build LNG storage facilities at key ports such as Ho Chi Minh City, Hai Phong, Can Tho, etc., and equip them with temperature management systems, fire safety monitoring, and real-time LNG consumption tracking. Furthermore, government agencies need to provide support through incentives for LNG infrastructure investment, shorten the licensing time for clean energy projects, and issue LNG safety standards. This will help businesses implement effective transportation and storage strategies, while simultaneously enhancing the reputation and competitiveness of Vietnam's agricultural supply chain in the international market.

Secondly, integrate green supply chain management with LNG resources. Businesses should adopt environmental management standards such as ISO 14001, monitor emissions monthly, and set targets for a 10-15% reduction in greenhouse gases to both improve economic efficiency and strengthen the sustainable reputation of the supply chain. In addition, businesses can establish emission control procedures, implement periodic environmental reporting, optimize transportation routes and warehouse management using LNG to reduce energy consumption, train employees in environmental and energy management, apply digital tools (IoT, GPS, route management software) to monitor energy efficiency, and build mechanisms to encourage initiatives that reduce emissions or energy costs by $\geq$10% in each department.

Thirdly, encourage technological innovation and leverage support policies related to LNG. Businesses should develop new technological solutions to improve LNG efficiency, such as implementing smart LNG energy management systems, digitizing transportation and warehouse routes, and applying software to forecast demand and optimize energy costs. Personnel need to receive regular training on new green technologies to increase adaptability and continuous innovation. The government and regulatory agencies should provide transparent incentive mechanisms, including financial support for LNG technology trials, expedited licensing of innovation projects, funding for personnel training, and promoting digital transformation in the supply chain.

Fourth, encourage international cooperation and the adoption of advanced technologies. Businesses and regulatory agencies need to proactively promote international cooperation, participate in carbon credit programs and international green logistics projects to access global standards. Specifically, businesses can sign cooperation agreements with foreign LNG suppliers, test advanced LNG vessel and vehicle technologies, and apply modern energy management solutions to optimize costs and reduce emissions. At the same time, they should build data sharing mechanisms with international partners to learn efficient LNG operation processes, improve demand forecasting capabilities, and enhance warehouse management. Vietnamese regulatory agencies should support businesses by promoting public-private partnerships to support research and development of LNG technology, organizing workshops and in-depth training on energy management and LNG operations. In addition, it is necessary to develop domestic LNG operating standards suitable for Vietnamese conditions, including storage facilities, LNG refueling stations, and transportation routes, to ensure safety, economic efficiency, and environmental protection, while enhancing the reputation and competitiveness of Vietnamese agricultural products in the global market.

Future research should focus on three key areas. First, expanding comprehensive comparisons of other clean energy sources (hydrogen, electricity, biogas) with LNG in terms of cost, emissions, and logistics performance. Second, developing quantitative models to assess the long-term impact of LNG on economic efficiency, the environment, and competitiveness. Third, explore the regulatory role of new factors such as international cooperation, carbon markets, and digital platforms to refine industry investment policies and strategies.

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