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Driving Innovation in Agri-Startups Through Sustainable Supply Chain Integration: Evidence from Vietnam

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ABSTRACT

Integrating into sustainable supply chains positively influences innovation efficiency in agri-startups. This study examines the impact of such integration on the innovation performance of 476 agri-startups in Vietnam. Using the Ordinary Least Squares (OLS) model, we assess the effects of key factors including market access, collaboration, risk management, high-tech applications, sustainable practices, and strategy on innovation outcomes. Regression analysis is also employed to identify the determinants driving the adoption of high-tech solutions that support sustainable supply chains. The results indicate that participation enhances operational efficiency, fosters technological adoption, and strengthens innovation and sustainability capacity. By engaging in sustainable practices and leveraging high-tech tools, agri-startups can improve product and process innovation while mitigating risks. Based on these findings, practical recommendations are provided for agri-startups to optimize their innovation capabilities through sustainable supply chain integration, contributing to Vietnam's national innovation initiatives and broader sustainable development objectives.

1. INTRODUCTION

Innovation is considered one of the most important indicators of development and a central factor guiding the progress of countries, particularly in developing economies. Experience has shown that innovation decisively contributes to productivity growth and sustainable development, becoming a key factor in mitigating and reversing the effects of climate change a major global challenge in which agriculture plays a preeminent role. Within this context, fostering innovation in the agricultural sector, especially through startup activities, is not only an economic priority but also a pathway to green transformation and rural revitalization. Recent studies across multiple countries provide evidence of the effectiveness of innovation policies in promoting national competitiveness and sustainability [1, 2].

Besides, start-ups play a significant role in both the economy and society. However, public innovation policies often focus on large companies, resulting in measures that do not reflect the realities of start-ups. Most policies targeting start-ups are narrow and generic, applying metrics and evaluation criteria designed for larger enterprises [3]. In fact, the path to innovation is far more complex for micro and small enterprises, including start-ups, due to resource limitations and structural constraints that hinder competitiveness and challenge the innovation process. Agri-startups, in particular, face unique challenges, such as limited access to capital and financing, which constrain investment in essential technologies and scaling. Meanwhile, insufficient technical expertise and digital infrastructure in rural areas impede the adoption of advanced solutions, including precision farming and smart irrigation. Regulatory barriers and fragmented supply chains further complicate market entry and expansion, while climate change and unpredictable weather pose significant risks to agricultural productivity. Moreover, the agri-startup ecosystem, though rapidly expanding, remains fragmented and highly sensitive to external shocks such as market fluctuations and global supply chain disruptions. Many young enterprises struggle to bridge the gap between technological innovation and sustainable commercialization due to limited integration with broader supply chain networks [4, 5]. Besides, the rapid pace of change in the economic environment, driven by innovation and expressed through digital transformation and high-tech applications, exposes the weaknesses of traditional agri-startup business models. Many enterprises struggle to adapt to evolving high-tech trends, and some have failed or gone bankrupt. Innovation in high-tech has fundamentally transformed the landscape for agri-startups, creating new challenges. However, it also opens up new opportunities for startups to participate in sustainable supply chains, where innovation, collaboration, and digital integration can jointly enhance resilience and competitiveness [6, 7].

In this context, integration into sustainable supply chains becomes a critical factor supporting agri-startups' adaptability to ever-changing conditions and high-tech requirements. Sustainable supply chains enable start-ups to effectively manage the flow of goods, information, and finances. Building fast, innovative, and highly adaptable supply chains enhances the resilience and growth potential of agri-startups in competitive markets [8]. More importantly, sustainable supply chain integration acts as a conduit for knowledge transfer, technological upgrading, and eco-innovation—essential drivers for agricultural transformation in emerging economies like Vietnam. Therefore, integrating into sustainable supply chains is a pressing issue, especially in regions with varying supply chain maturity, and necessitates the development of tailored recommendations and policies. Participation in such chains also helps mitigate operational and market challenges [9].

Against this backdrop, agri-startups offer a compelling case to investigate how sustainable supply chain participation can drive innovation. The goals of agricultural modernization and sustainability require a deeper understanding of how supply chain linkages, digital technologies, and collaborative ecosystems interact to foster innovation performance. So, this study employs an OLS model to analyze the impact of participating in a sustainable supply chain on innovation among agri-startups. Additionally, it uses a regression model to identify the factors related to high-tech applications that influence sustainable supply chains. Specifically, the study examines how high-tech adoption, resource collaboration, and sustainable practices mediate the relationship between supply chain integration and innovation outcomes. This study is novel and unique because it integrates an analysis of the impact of participating in sustainable supply chains on the innovation efficiency of agri-startups, while also considering factors such as high-tech applications, collaboration, risk management, and sustainable practices to clarify how supply chain participation fosters innovation capacity. By providing empirical evidence from Vietnam, this research contributes to the global discourse on how sustainable supply chain integration can be leveraged as a strategic enabler for innovation-led growth in agri-startups within emerging economies leveraging their agricultural advantages for development like Vietnam.

2. LITERATURE REVIEW

2.1 Innovation in agri-startups

Innovation capacity refers to a firm's ability to innovate consistently throughout the entire innovation process [10]. This process is continuous and characterized by three main steps: efforts, activities, and results. Efforts encompass all resources, such as human and financial capital, that a firm invests in innovation activities, including R&D, training, and study tours, which may lead to innovations. Agri-startups play a vital role in transforming modern agriculture by integrating technology and innovative business models to enhance productivity, sustainability, and profitability. These ventures apply advanced tools such as precision agriculture, biotechnology, robotics, and digital platforms to improve efficiency and transparency across the agricultural value chain [2, 4, 11]. Innovation in agri-startups can be categorized into domains including technology innovation, farming practice innovation, market access innovation, and business model innovation. Technology innovation emphasizes the application of advanced tools and digital technologies to enhance efficiency, accuracy, and environmental performance. Innovation in agri-startups is transforming by addressing challenges such as climate change, resource scarcity, and the need for sustainable practices [12].

Dadi et al. [11] highlight the role of technological innovations, relating to the use of IoT, AI, and automation, to improve efficiency, yield prediction, and resource management in agriculture. Farming practice innovation focuses on adopting sustainable agricultural methods that optimize inputs and reduce environmental impact [1, 13]. Agri-startups employ new business models that disrupt traditional agricultural practices, such as precision agriculture, farm-to-fork logistics, and direct-to-consumer sales platforms. These innovations positively impact sustainability and the environment by reducing agriculture's ecological footprint through sustainable farming practices, organic farming, and climate-smart agriculture [6, 14, 15].

Furthermore, market access innovation aims to improve farmers' and startups' connection to markets through digitalization and transparency. Innovations in this domain facilitate smallholder farmers' participation in value chains by leveraging digital tools such as mobile platforms, e-commerce applications, and blockchain-based supply chain traceability. Innovations in market access for smallholder farmers focus on utilizing mobile platforms for market information, e-commerce solutions, and blockchain-based supply chain traceability [11, 16]. Besides, business model innovation in agri-startups reflects the development of new value propositions and revenue models aligning with sustainability goals and consumer trends. Several studies highlight that policies and regulations influence innovation in agricultural startups, particularly through intellectual property, biotechnology, financing, infrastructure, and digital access. Strengthening leadership, fostering strategic partnerships, and adapting to local contexts are essential for their success [17, 18].

The innovation capacity of a firm is heavily dependent on access to information, which is crucial for achieving a sustainable competitive advantage. This advantage is realized by effectively leveraging both internal and external resources. Internal resources, such as R&D infrastructure, qualified staff, managerial experience, openness to new ideas, financial structure, and firm size, play a significant role in this process [5]. Agri-startups benefit from an environment that promotes the active involvement of both suppliers and customers in the innovation process [17].

Additionally, engagement in a sustainable supply chain is particularly vital for agri-startups to enhance their innovation capacities. The supply chain serves as a platform where a firm's internal and external resources are integrated and transformed into innovation capabilities. Engagement in sustainable supply chains is essential for agri-startups to strengthen their innovation capacity by integrating internal and external resources into innovative capabilities [19]. Effective supply chain integration enhances collaboration, optimizes resource use, and reduces risks in innovation implementation [20]. By leveraging complementary technologies and partnerships, agri-startups can improve innovation outcomes and achieve sustainable competitive advantages [17].

2.2. Sustainable supply chains and factors

A sustainable supply chain is a network of businesses and processes that manage the flow of goods and services while minimizing environmental, social, and economic impacts [13]. It incorporates sustainable practices throughout the supply chain, from sourcing raw materials to production, distribution, and end-of-life disposal or recycling. According to Carter and Rogers [21], the goal of a sustainable supply chain is to reduce carbon footprints, ensure ethical labor practices, support local communities, and enhance long-term economic viability without compromising the ability of future generations to meet their needs. In agriculture, it promotes practices such as precision farming, organic production, and fair trade to address resource depletion and social inequities [22]. Emphasizing transparency, technology adoption, and stakeholder collaboration enhances efficiency, resilience, and long-term sustainability across the agricultural value chain.

Several studies identify various factors affecting the sustainable supply chain, including high-tech applications, logistics, distribution, market access, sourcing, collaboration, sustainable practices, risk management, and strategy. According to Mastos et al. [3], the success of effective supply chain management relies on strong linkages between providers and recipients, thereby ensuring timely delivery and accurate transactions. In particular, high-tech applications such as IoT, blockchain, AI, drones, and digital platforms play a key role in enhancing supply chain visibility, traceability, and efficiency in agri-startups, as they support the monitoring of goods and information flows. Moreover, these technologies, together with cold chain management and optimized transportation, reduce losses, lower costs, and maintain product quality [11, 23]. Furthermore, logistics and distribution are crucial for moving perishable products efficiently from farm to market. However, challenges such as poor rural infrastructure or fragmented supply chains can be mitigated through rural logistics hubs, cooperatives, and digital aggregation platforms [24]. In addition, sustainable logistics practices—including eco-friendly transport, renewable energy in storage, and sustainable packaging—contribute to environmental stewardship while simultaneously enhancing operational efficiency [9].

Similarly, market access and sourcing significantly affect agri-startups' performance. Specifically, efficient distribution channels, access to market information, financial resources, and supportive regulatory frameworks improve revenue streams and enable sustainable growth [1]. In this regard, digital marketplaces, fintech, and mobile applications help farmers connect directly with buyers, thereby ensuring transparency, traceability, and access to finance, while also supporting rural development and strengthening supply chain resilience [25]. Equally important, sustainable practices—including organic farming, eco-friendly packaging, precision agriculture, and renewable energy use—help balance profitability with environmental and social responsibility, thus enhancing overall supply chain sustainability [3, 9]. At the same time, risk management remains central, as it addresses climatic, market, operational, financial, technological, and regulatory uncertainties. Accordingly, strategies such as diversification, insurance, technology adoption, and proactive supply chain planning improve resilience and operational stability.

Besides, collaboration with suppliers, distributors, technology providers, research institutions, and farmer cooperatives strengthens supply chain efficiency, market access, and innovation [25]. In particular, strategic partnerships, joint ventures, and alliances integrate resources across sectors, thereby reducing costs and fostering growth. Moreover, regulatory and policy support, including simplified processes, financial incentives, and IP protection, further enable agri-startups to innovate, expand, and maintain supply chain resilience [26, 27].

2.3 Impact of integrating the sustainable supply chain on innovation

Some studies highlight that integrating agri-startups into sustainable supply chains is increasingly recognized as a catalyst for innovation within the agricultural sector. According to Kühne et al. [10], participation in such supply chains compels these startups to develop technologies and practices aligned with environmental and social sustainability goals. This often results in innovations aimed at reducing waste, optimizing resource use, and enhancing traceability throughout the supply chain. Effective integration within the supply chain supports innovation capacity and mitigates the risks associated with implementing innovations, such as through joint cost management [28]. The supply chain serves as a critical platform where both internal and external resources are combined and transformed into innovative capacities [19]. By leveraging these resources, agri-startups can become more innovative and achieve a sustainable competitive advantage. Utilizing complementary capacities and technologies within the supply chain enables startups to address challenges related to innovation implementation [5]. Participation in such a chain enhances market access, competitiveness, and brand differentiation, allowing agri-startups to respond to rising consumer demand for sustainably produced goods and foster customer loyalty. Moreover, sustainable supply chains improve operational efficiency through resource optimization, energy-efficient technologies, and waste reduction, while also increasing resilience by diversifying suppliers and reducing reliance on single sources. Importantly, engagement in sustainable practices encourages innovation, as startups develop new processes, products, and business models to meet ESG criteria, manage environmental risks, and attract funding, ultimately supporting long-term growth and adaptability [15, 28].

Besides, some studies show that sustainable supply chains provide startups with access to networks of like-minded partners and stakeholders who prioritize sustainability. This fosters a collaborative environment that enhances knowledge sharing and co-innovation, supplier flexibility, supply agility, and company performance are interrelated, and IT capabilities support the adoption of supply chain technologies and improve operational performance [12, 25]. Additionally, Shashi [26] uses structural equation modeling to show that high firm performance necessitates strong external and internal integration, as well as significant value addition. Involvement in sustainable supply chains promotes the adoption of precision agriculture technologies, which reduce environmental impact and increase productivity. The emphasis on transparency and traceability in these supply chains often leads to the integration of blockchain and IoT technologies, enhancing visibility and accountability of supply chain operations [19]. This adoption supports startups in offering innovative solutions that further improve supply chain efficiency and sustainability.

Moreover, engaging with sustainable supply chains can enhance an agri-startup's market positioning by addressing the increasing consumer demand for sustainably produced food. This market advantage often drives further innovation, as startups seek to differentiate their products and services in a competitive landscape [5]. However, Weaver [20] points out challenges, including the significant investments needed to meet sustainability standards and the potential for increased operational complexity. Despite these challenges, Zhow et al. [13] find that the overall impact of integrating into sustainable supply chains is positive. It not only fosters business growth but also advances broader environmental and social goals. The symbiotic relationship between sustainable supply chains and agri-startups is crucial for driving innovation that aligns with global sustainability objectives, ultimately benefiting both the agricultural sector and society at large.

In general, empirical studies consistently demonstrate a positive relationship between participation in sustainable supply chains and the innovation of agri-startups. Sustainable supply chains play a critical role in enhancing business operations by improving access to information, capital, and markets. Literature identifies various determinants affecting supply chains, including technology, logistics, market access, collaboration, sustainable practices, and risk management. For agri-startups, these factors are particularly shaped by high-tech applications such as IoT, AI, precision farming, blockchain-based traceability, and digital platforms, which enable efficient, transparent, and resilient supply chain operations. The reliance on advanced technologies distinguishes agri-startups from traditional agricultural enterprises, making tech adoption a central driver of sustainable supply chain performance. Besides, some studies have employed various models, such as linear regression, binomial logistic regression, multinomial logit models, and structural equation modeling, to explore the impacts of sustainable supply chains on operational performance and innovation. However, while many studies address these factors and their influence on agri-startups' effectiveness and innovation, there is a notable gap in research specifically focusing on the impact of sustainable supply chains on innovation in developing countries like Vietnam.

3. MATERIALS AND METHODS

To examine the impact of sustainable supply chain participation on innovation, data. Data were collected from 476 agri-startups located in regions recognized for their representative and high-performing agri-startup ecosystems. These included Song Hong Delta (105 firms), South-Central (213), and Cuu Long Delta (158), areas known for hosting exemplary agri-startups with active participation in sustainable supply chains. Access to participants was coordinated with local authorities, who helped arrange face-to-face interviews with startup founders and managers. The sample was selected from official lists provided by local authorities, focusing on startups demonstrating effective integration into supply chains.

A structured questionnaire was administered (in Vietnamese, with careful translation and back-translation from the original English version to ensure accuracy). We engaged local partner organisations to facilitate the survey. Data were collected primarily via in-person or online interviews with founders or supply chain managers of the startups. The structured questionnaire comprised items covering high-tech applications, innovation capacity, and sustainable supply chain participation, alongside demographic information such as gender, age, education, job level, tenure, location, access to logistics hubs, and broadband infrastructure.

Table 1. Operationalization of variables

Variables	Definition	Source
Innovation in agri-startups	Technological advancements, sustainable farming practices, enhanced market access, and new business models.	[2, 4, 10, 11, 12, 14]
Sustainable supply chain	Incorporating environmental, social, and economic considerations into its management practices to achieve long-term sustainability including environmental sustainability, social sustainability and economic sustainability.	[13, 20, 22, 29]
Hi-tech applications	Use of advanced technologies to enhance productivity, efficiency, and sustainability in agriculture	[1, 13]
Logistics and distribution	Ensure efficient, transparent, and traceable product flow from farms to consumers	[6, 15]
Market access and sourcing	Ability to reach and supply products to customers through channels	[11, 16, 17]
Collaboration	Process of sharing data and forecasts and enhancing trust and transparency among parties	[6, 15, 17]
Sustainability practices	Reducing pollution and improving agricultural efficiency to optimize resources and minimize waste	[6, 15, 20]
Risk management	Reduce production risks by analyzing risks and forecasting weather	[17, 19, 28]
Strategy	Strategy to support sustainable development.	[17, 18, 20]

Source: Authors' collection (2025)

Table 2. Measurement items

Factors	Code	Cronbach's α	Example Items
Innovation (INA)	INA1	0.591	"Our startup frequently adopts new technologies to increase productivity".
	INA2	0.888	"The startup improves its production processes toward sustainability".
	INA3	0.894	"We develop or introduce new products or services".
	INA4	0.886	"The startup experiments with new business models or market solutions".
Sustainable Supply Chain (SSC)	SSC1	0.853	"Our supply chain reduces environmental impacts through efficient resource use, emission reduction, waste management, and circular practices".
	SSC2	0.842	"Our supply chain supports social well-being by ensuring worker well-being, community development, stakeholder engagement, and traceability".
	SSC3	0.716	"Our supply chain strengthens economic performance by productivity, product quality and market expansion".
Hi-Tech Application	HT	0.778	"We use high technologies to monitor production conditions (soil, water, temperature)".
Logistics & Distribution	LD	0.778	"Our logistics system ensures timely and traceable deliveries with adequate cold-storage solutions suitable."

Factors	Code	Cronbach's α	Example Items
Market Access & Sourcing	MA	0.678	"The startup sells directly to consumers through e-commerce platforms, new distribution channels (markets, supermarkets)."
Collaboration	CO	0.827	"We share production and demand data with suppliers and partners".
Sustainability Practices	SP	0.837	"We apply techniques to reduce pollution and energy consumption".
Risk Management	RM	0.849	"We use forecasting models to reduce weather- and disaster-related risks, contingency plans in the supply chain (e.g., alternative suppliers)".
Strategy	ST	0.833	"The company has a clear digital transformation strategy; Leadership is committed to investing in automation and digitization".

Source: Author's survey (2025)

Table 3. Exploratory factor analysis for factors impacting the sustainable supply chains of agri-startups

Reliability Statistics				
	Cronbach's Alpha		N of Items	
	0.856		16	
Rotated Component Matrix[a]				
	Component			
	1	2	3	4
IoT		0.796		
AI		0.792		
Yield prediction		0.703		
Automatic		0.688		
Resource management		0.804		
Nano-tech	0.776			
Eco- friendly production	0.848			
Mobile platform	0.782			
E-commerce	0.737			
Blockchain	0.802			
Precision farming	0.682			
Farm-to-fork logistic				0.861
Direct–to-cosumer				0.920
SSC1			0.853	
SSC2			0.842	
SSC3			0.716	

KMO and Bartlett's Test		
	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.831
Bartlett's Test of Sphericity	Approx. Chi-Square	1434.468
	df	120
	Sig.	0.000

Source: Author's survey (2025)

A content validity assessment was conducted with five experts, including agricultural economics professors, a supply chain specialist, a sustainability researcher, and an agri-innovation policy expert. Using a four-point scale, they evaluated each item's relevance, clarity, and applicability following Lynn (1986). Besides, Item-CVI values ranged from 0.75 to 1.00 across dimensions, while Scale-CVI/Ave reached 0.93 (environmental), 0.90 (social), and 0.92 (economic), indicating strong content validity. Items scoring below 0.78 were revised for better precision. A pilot test with 30 respondents assessed the instrument's clarity and internal consistency. Cronbach's Alpha values were acceptable: 0.78 for environmental sustainability, 0.72 for social sustainability, and 0.76 for economic sustainability. Items with item-total correlations below 0.30 were reworded; no items were removed. The results confirm that the instrument is sufficiently reliable for full-scale data collection (see Tables 1-3).

All constructs were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree. Table 4 presents the control variables and their justification, while Table 1 reports the operationalization of key variables used in the empirical analysis.

Building on prior studies that primarily employ mean regression or correlation approaches, this study applies an Ordinary Least Squares (OLS) regression model to examine the effect of sustainable supply chain participation on innovation in agri-startups. The baseline model is specified as follows:

$$Y_i = \beta_0+\beta_1 x_{i1}+\beta_2 x_{i2}+...+\beta_p x_{ip}+\epsilon$$

where, for i = n observations:

Y_i = dependent variable (agri-startups' innovation)

x_i = explanatory variables (hi-tech, logistic, market access, collaborate, sustainable practices, risk management, strategy)

β_0 = y-intercept (constant term)

β_p = slope coefficients for each explanatory variable

ϵ = the model's error term (also known as the residuals).

The model is a statistical tool that enables analysts to predict the value of one variable based on the known values of another variable. This study is innovative in its application of the OLS regression model to explore how variations in high-tech applications influence the effects of sustainable supply chains including logistics and distribution, market access and sourcing, collaboration, sustainability practices, risk management and strategy. Besides, the study uses a regression model to identify the factors related to high-tech applications that influence sustainable supply chains. In this analysis, the dependent variable is the sustainable supply chain, while the independent variables include various high-tech applications such as IoT, AI, yield prediction, automation, resource management, nanotechnology, eco-friendly production, mobile platforms, e-commerce, blockchain, precision farming, farm-to-table logistics, and direct-to-consumer sales platforms (see Table 4).

The study also employed a dual estimation approach combining Propensity Score Matching (PSM) and Two-Stage Least Squares (2SLS). PSM was applied to address observable selection bias between agri-startups participating in sustainable supply chains and non-participants, using a logit model with firm and founder characteristics as covariates. Covariate balance improved substantially, with mean standardized differences decreasing from 0.21 to 0.06, and consistent ATT estimates indicated an increase in innovation performance of 0.18-0.22 points ($p < 0.05$). To address potential endogeneity from unobserved managerial capability and reverse causality, a 2SLS model was estimated using access to broadband expansion and distance to the nearest incubation or extension center as instruments. The first-stage results showed strong relevance (F-statistic = 18.2), and Hansen's J-test confirmed instrument validity ($p = 0.26$), with a positive and robust effect on innovation (0.23 points). A Durbin-Wu-Hausman test comparing OLS and 2SLS estimates failed to reject the null hypothesis of exogeneity ($p>0.05$), suggesting no statistically significant difference between the two estimators; therefore, OLS is retained as the preferred specification due to its efficiency. Furthermore, the results indicate that the average age of respondents is approximately 31.98 years. The workforce is predominantly male, comprising 62.13% of the total. The average level of education is over 15 years of schooling, and agri-startups related to farming are more common, with an average score of 2.04. According to the survey, the average number of years since business establishment exceeds 8 years. Additionally, the average annual revenue of these startups ranges from 100 VND to 500 million VND per month across the three regions.

Table 4. Control variables and justification

Control Variable	Operationalization	Items
Age	Respondent's actual age (years)	Years
Education	Actual schooling years	Years
Gender	Gender of respondents	1 = Male 2 = Female
Agri-startup types	Agri-startup types defined by products	1 = Crop farming 2 = Livestock production 3 = Aquaculture production 4 = Agricultural services
Region	Locations of Agri-startups	1 = Cuu Long Delta 2 = South Central region 3 = Song Hong Delta
Startup years	Number of years from the time the business was established	Years
Revenue	Monthly revenue (million VND)	1 = > 100 million VND 2 = from 100 million to 500 million VND 3 = 500 – 1000 million 4 = < 1,000 million
Job level		1 = APS level 2 = Executive level
Access to logistics hubs	Accessibility to logistics hubs	1 = inaccessible 2 = accessible 3 = easily accessible
Access to broadband expansion	Capacity for local broadband expansion	1 = inaccessible 2 = accessible 3 = easily accessible

4. DISCUSSIONS

4.1 Impact of integrating sustainable supply chains on innovation in agri-startups

Table 5 reports the OLS regression results examining how participation in sustainable supply chains influences innovation across four dimensions of agri-startups. The results show that elements and their scales have Cronbach Alpha = 0.859 (>0.7); KMO = 0.835 (>0.5), Bartlett test with significant = 0.000, Eigen value = 1.201 (>1), Approx.Chi-Square is 62.62. Variables have factor loading from 0.593 to 0.772 (>0.5). The F-test for the regression model is significant ($p < 0.05$), indicating overall statistical fitness. All variables show significant effects with p-values below 0.05.

The results of the OLS model show that a notable finding is the role of risk management, which is the strongest and most consistent positive effect across models, particularly in business model innovation (0.320). This result underscores that the ability to anticipate disruptions, diversify suppliers, and adopt forecasting tools significantly enhances the resilience and innovative capacity of agri-startups. Effective risk management enables firms to allocate resources more efficiently, minimize operational interruptions, and remain adaptive, consistent with previous studies emphasizing risk governance as a critical driver of firm-level innovation.

Besides, hi-tech applications (IoT, AI/ML, blockchain) also contribute positively to innovation, although their coefficients remain modest (ranging from 0.020 to 0.124). This finding suggests that while the adoption of advanced technologies enhances efficiency and supports innovation, many agri-startups may still be in the early stages of digital adoption or face barriers such as high investment costs and limited digital skills. The positive association aligns with the literature [23], reinforcing that digital transformation remains an essential but underutilized driver of innovation in the agricultural sector.

Collaboration emerges as another influential factor, with consistently positive coefficients across all innovation categories. Participation in networks, data sharing with partners, and coordination mechanisms enable startups to access technical expertise, share resources, and reduce uncertainties. This aligns with theories of relational collaboration, which highlight how inter-organizational partnerships foster knowledge exchange and co-innovation. Similarly, strategic orientation shows positive effects in all models (0.077-0.160). Agri-startups with clear digital transformation strategies and leadership commitment to technology investment demonstrate stronger innovation outcomes. This finding echoes Dyer and Singh's view that strategic clarity plays a crucial role in enabling firms to realize innovation benefits through resource alignment and goal-driven actions [30].

Although sustainability practices have positive coefficients across models, the effects are relatively small (0.020-0.063). This suggests that while environmental and social initiatives contribute to innovation, many agri-startups may still regard sustainability as compliance-driven rather than innovation-driven. As sustainability practices mature, stronger impacts on innovation might emerge, as documented in studies emphasizing how sustainability enhances competitiveness, market access, and long-term efficiency.

Table 5. Determinants of sustainable supply chains impacting innovation in agri-startups

Variables	Model 1 (Technology Innovation)		Model 2 (Farming Practice Innovation)		Model 3 (Market Access Innovation)		Model 4 (Business Model Innovation)	
	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err
Age	0.003	0.083	0.005	0.091	-0.010	0.016	0.006	0.701
Gender	0.027	0.061	0.077	0.081	0.019	0.074	0.049	0.085
Education	0.149	0.149	0.023	0.059	0.009	0.054	-0.232	0.063
Type	0.001	0.001	0.354	0.146	-0.144	0.116	0.003	0.086
Labor	0.015	0.074	-0.088	0.002	0.002	0.023	0.027	0.002
Region	-0.047	0.041	-0.097	0.072	-0.072	0.066	0.668	0.068
Access to logistics hubs	0.702	0.058	0.773	0.040	0.788	0.037	0.169	0.043
Access to internet	0.068	0.061	0.744	0.057	0.104	0.057	0.053	0.059
Hi-tech application	0.124	0.073	0.036	0.058	0.087	0.052	0.020	0.056
Logistics & distribution	0.051	0.063	-0.246	0.072	0.015	0.054	0.040	0.062
Market and sourcing	0.045	0.071	0.025	0.062	0.138	0.066	0.042	0.060
Collaboration	0.225	0.069	0.171	0.071	0.103	0.065	0.106	0.067
Sustainability practices	0.061	0.044	0.063	0.068	0.048	0.061	0.020	0.065
Risk management	0.257	0.076	0.061	0.042	0.027	0.039	0.320	0.044
Strategy	0.160	0.106	0.077	0.074	0.113	0.068	0.137	0.070
Cons	0.559	0.451	0.052	0.445	0.787	0.384	0.544	0.393
Prob>F	0.000		0.000		0.000		0.000	
R-squared	0.614		0.623		0.704		0.557	
Adj R-squared	0.596		0.697		0.690		0.556	
Root MSE	0.711		0.644		0.641		0.779	

Source: Author's survey (2025)

Several control variables such as age, type of production, labor size, and region, show mixed or insignificant effects, indicating that demographic and structural characteristics play a less central role compared to strategic, technological, and collaborative factors. Notably, logistics and distribution exhibit a negative association with farming practice innovation (-0.246), possibly reflecting the challenges of infrastructure gaps, transportation costs, or cold-chain limitations that hinder the adoption of advanced farming techniques.

Furthermore, a comparative assessment of the four regression models reveals substantial differences in how these factors shape distinct types of innovation. Model 1 related to technology innovation demonstrates the strongest influence from risk management (0.257), collaboration (0.225), and strategic orientation (0.160), suggesting that technological innovation depends heavily on coordinated partnerships, structured planning, and the ability to anticipate operational risks. Model 2 related to farming practice innovation shows overall weaker effects, with distance (0.773) and access to the internet (0.744) emerging as the most important drivers, indicating that improvements in farming techniques are more sensitive to geographical accessibility and digital connectivity than to internal capabilities. According to the results on market access innovation in Model 3, this model demonstrates the highest explanatory power ($R^2 = 0.704$). The findings show that market and sourcing (0.138), collaboration (0.103), and hi-tech application (0.087) make substantial contributions. This indicates that innovations in market access are primarily driven by external linkages and digital tools. Finally, the predominant role of risk management is highlighted with 0.320, implying that business model transformation requires robust risk-mitigation mechanisms and strong strategic foresight in the model 4 related to pertaining to business model innovation. These differences collectively indicate that while supply chain participation encourages innovation across all dimensions, each type of innovation responds to a unique configuration of drivers shaped by both internal capabilities and external conditions.

The results confirm that integrating into sustainable supply chains encourages agri-startups to innovate by exposing them to higher market demands, quality standards, and collaborative ecosystems. To maximize innovation outcomes, targeted policies such as digital skill training, risk management support, logistics infrastructure upgrades, and incentives for sustainability practices are essential. Strengthening these areas will help build a more competitive, efficient, and resilient agri-startup ecosystem.

4.2 The impact of factors on the sustainable supply chains of agri-startups

The regression model results in Table 6 provide a comprehensive view of the factors influencing environmental, social, and economic sustainability in the supply chains of Vietnamese agri-startups. All three models are statistically significant (F-test, $p < 0.05$), indicating the adequacy of the model specifications (see Tables 2 and 3). Across the models, the findings highlight the role of high-tech applications, logistics, digital platforms, and sustainability-oriented practices in shaping the performance of sustainable supply chains.

For environmental sustainability, several factors exhibit strong positive effects. Farm-to-fork logistics is the most influential factor, indicating that short and transparent food supply routes substantially strengthen environmental outcomes by reducing emissions, shortening transportation distances, and minimizing waste with 0.509. Eco-friendly production also contributes significantly, emphasizing the importance of environmentally responsible production methods in reducing pollution and improving resource efficiency with 0.363. In addition, resource management (0.278) positively affects environmental sustainability, suggesting that systematic control of inputs such as water, fertilizer, and energy helps startups optimize resource use and limit environmental degradation. Conversely, certain high-tech variables including IoT, AI, and yield prediction exhibit small or negative coefficients, implying that the environmental benefits of digital technologies may depend on the maturity of implementation or supporting infrastructure.

Table 6. The impact of factors on the sustainable supply chains of agri-startups

Variables	Model 1 (Environment Sustainability)		Model 2 (Social Sustainability)		Model 3 (Economic Sustainability)	
	Coef.	SE	Coef.	SE	Coef.	SE
Gender	-0.013	0.067	0.155	0.118	0.097	0.129
Education	-0.080	0.049	-0.076	0.083	-0.089	0.067
Type	0.157	0.074	-0.027	0.112	0.142	0.094
Labor	-0.007	0.006	-0.005	0.001	-0.001	0.008
Region	0.141	0.056	-0.395	0.093	-0.018	0.075
IoT	-0.028	0.067	-0.252	0.112	-0.034	0.089
AI	-0.054	0.057	0.024	0.095	0.023	0.076
Yield prediction	0.033	0.051	-0.088	0.088	-0.034	0.071
Automatic	0.112	0.073	0.160	0.118	0.072	0.094
Resource management	0.278	0.042	0.045	0.071	-0.023	0.054
Nano-tech	0.034	0.058	0.045	0.071	0.028	0.072
Eco-friendly production	0.363	0.045	0.081	0.093	0.076	0.061
Mobile platform	0.045	0.554	-0.062	0.091	0.106	0.073
E-commerce	0.213	0.045	0.106	0.076	0.131	0.061
Blockchain	0.063	0.056	0.061	0.093	0.119	0.075
Precision farming	0.048	0.053	0.448	0.088	0.077	0.072
Farm-to-fork logistic	0.509	0.048	-0.023	0.081	0.206	0.051
Direct-to-consumer sales platform	0.066	0.053	0.078	0.084	-0.052	0.067

Source: Author's survey (2025)

Model 2 related to social sustainability is driven primarily by precision farming with 0.448, which demonstrates the strongest effect among all predictors. Precision farming enhances labor safety, reduces physical workload, and supports community well-being through more stable and predictable production processes. Other contributors include automation (0.160), eco-friendly production (0.081) and direct-to-consumer platforms (0.078), all of which promote improved working conditions, stronger producer–consumer trust, and greater social transparency. However, factors such as IoT (–0.252) and region (–0.395) show negative associations, suggesting disparities in technology readiness or challenges related to regional infrastructure. This indicates that achieving social sustainability requires not only technology adoption but also equitable access and supportive institutional conditions.

Economic sustainability in the Model 3 is significantly influenced by digital market channels and logistics innovations. Farm-to-fork logistics (0.206) and e-commerce (0.131) show positive and meaningful effects, implying that startups capable of accessing digital markets and shortening the supply chain experience higher returns, improved price stability, and reduced transaction costs. Blockchain (0.119) also enhances economic sustainability by improving traceability and product credibility, thereby supporting premium pricing and market expansion. While eco-friendly production (0.076) and precision farming (0.077) demonstrate moderate positive effects, the insignificant or negative coefficients for some high-tech variables (e.g., IoT, yield prediction) suggest that these technologies may require substantial investment before economic gains materialize.

The results indicate that sustainable supply chains in agri-startups are shaped by a combination of technological adoption, environmentally responsible practices, and modern logistics systems. Farm-to-fork logistics emerges as the most consistent driver across all three sustainability pillars, particularly environmental and economic dimensions. Meanwhile, precision farming plays a dominant role in social sustainability. The findings underscore the need for targeted policies such as capacity building, subsidy support for digital tools, and investments in logistics infrastructure to enable agri-startups to fully leverage sustainable supply chain practices and enhance long-term resilience.

5. CONCLUSION

This study investigates the influence of sustainable supply chains on the innovation performance of Vietnamese agri-startups by employing OLS regression models using a dataset of 476 agribusiness ventures. The findings advance the existing literature by clarifying how sustainable supply chain practices foster innovation capacity within agri-startups. Results from the OLS model indicate that targeted policy interventions such as digital skills training, risk management support, upgrades to logistics infrastructure, and incentives promoting sustainability practices play a critical role in strengthening innovation outcomes. Meanwhile, the regression model highlights that farm-to-fork logistics consistently acts as a key driver of sustainability, exerting strong effects across all three pillars, with particularly notable impacts on environmental and economic dimensions. Some recommendations such as:

Firstly, government policies play a crucial role in advancing high-tech adoption and innovation among agri-startups. Through financial support, R&D funding, infrastructure investment, education, regulation, and sustainability promotion, governments create an enabling environment that boosts efficiency and productivity. Key measures include grants and subsidies for sustainable practices (organic farming, renewable energy, water conservation), funding for precision farming and biotechnologies, and training programs to improve technical skills. Monitoring metrics further ensures accountability and continuous improvement.

Secondly, agri-startups should adopt innovation-driven and sustainable strategies supported by strategic government interventions. Recommended policies include: (1) grants and tax incentives for R&D and advanced technologies; (2) government-backed venture capital to reduce risk and attract private investment; (3) rural infrastructure development (broadband, logistics); (4) subsidies for sustainable practices; and (5) simplified regulations and certification to enhance supply chain participation.

Thirdly, the government should also promote farm-to-table logistics by investing in local food infrastructure, simplifying regulations for small producers, and funding R&D to improve logistics efficiency. Public campaigns can raise consumer awareness of local food benefits, while partnerships with markets, restaurants, and CSA programs strengthen direct-to-consumer sales.

Fourthly, the government can support eco-friendly production in agri-startups through several measures. These include providing financial incentives such as grants, tax breaks, and subsidies for businesses that adopt eco-friendly production methods. Implementing regulations that promote sustainable practices, such as stricter emissions standards, waste reduction mandates, and sustainable sourcing requirements, is also crucial. Additionally, offering training programs to educate producers, manufacturers, and supply chain managers on the benefits and methods of eco-friendly production can be beneficial. Promoting public awareness about the importance of sustainable products will help drive consumer demand and support for eco-friendly supply chains.

Finally, the government can support precision farming in agri-startups through several key policies. These include providing subsidies, grants, and low-interest loans to encourage the adoption of precision farming technologies. Investing in research and development to create affordable and accessible precision farming tools and technologies is also essential. Additionally, offering training programs for farmers to learn how to implement and benefit from precision farming practices can facilitate their adoption. Developing robust data infrastructure to integrate precision farming data into supply chain management systems further supports the effective use of these technologies.

This study has certain limitations, as it focused solely on Vietnamese agri-startups, which may limit the generalizability of the findings. Future research should broaden the scope to include other sectors and consider additional individual or organizational factors influencing innovation. Expanding the analysis to other aspects of agri-startups and industries will provide a more comprehensive understanding of sustainable supply chain impacts.

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