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Pragmaticality of Hi-Tech Innovation and Environmental Sustainability in Organic Agri-Startups: The Role of Sustainable Supply Chains

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Abstract: This study investigated the impact of hi-tech innovation on environmental sustainability in the supply chains of organic agri-startups by using an Ordinary Least Squares (OLS) model. The results indicated that environmental sustainability in organic agri-startups was driven most strongly by eco-friendly production (0.440), followed by blockchain (0.269) and mobile platforms (0.250), while farm-to-table logistics (−0.093) and nano-technology (−0.033) showed negative impacts. Using a regression-based prioritisation approach, the study revealed that organic agri-startups adopted hi-tech innovation pragmatically. They could then prioritise technologies to enhance production processes, ensure organic compliance, and stabilise operations under environmental uncertainty. Built upon these findings, the study strengthened the literature on sustainable and organic entrepreneurship by demonstrating how behavioural constructs shaped decision making. This divergence from previous studies contributes to behavioural decision theory in agri-startups, thus highlighting the importance of analyzing not only what entrepreneurs value but also what they choose, given constraints in resources, knowledge, and operational risk.

Keywords: Sustainable supply chain; Organic agri-startups; High-tech innovation; OLS model; Entrepreneurial behavior

1. Introduction

Innovation is widely recognised as a key driver of national development, particularly in developing countries, where it plays a central role in enhancing productivity and advancing environmental sustainability. Evidence increasingly showed that hi-tech innovation was essential for mitigating and even reversing the impacts of climate change, an area in which agriculture is especially critical by enabling more efficient use of resources, reducing emissions, and supporting resilient production systems.

The transition toward environmentally sustainable agricultural systems has become an urgent global priority, particularly as climate change intensifies pressure on food production, resource availability, and ecological stability. Organic agriculture, with its emphasis on ecological balance and reduced chemical dependence, has emerged as a promising pathway toward sustainable food systems (Sharma, 2025). Yet, despite its environmental advantages, organic production faces persistent challenges related to productivity, climate vulnerability, traceability, and inefficiencies of the supply chain. In this context, hi-tech innovation ranging from Internet of Things (IoT)-enabled monitoring to blockchain traceability and eco-friendly production technologies, has progressively become recognised as a critical driver of environmental sustainability (Hasan et al., 2024; Kim et al., 2020).

Recent research on sustainability and technological innovation in agri-food supply chains has predominantly focused on large agribusinesses or technology-intensive firms, thus leaving smaller and resource-constrained actors relatively underexplored. A limited body of literature has begun to acknowledge the role of advanced technologies in enhancing agricultural sustainability within organic agri-startups characterized by resource scarcity, high uncertainty, and strong environmental commitments (Shubham et al., 2025; Suttidee et al., 2025). Meanwhile, existing studies have documented the positive effects of sustainable supply chain on firms' performance, competitiveness, and environmental outcomes (Ashby et al., 2012; Fu et al., 2022; Kang et al., 2018), as well as the enabling role of hi-tech innovations such as Internet of Things (IoT), blockchain, and advanced analytics in improving environmental performance and operational efficiency within the supply chains (Kühne et al., 2010; Loon et al., 2018; Tsai & Lasminar, 2021). However, the majority of the literature examined the integration of sustainable supply chain and hi-tech adoption as parallel or complementary strategies, with limited attention to their interaction and mutually reinforcing mechanisms, particularly in the context of agri-startups. Moreover, few empirical evidence remained on how early-stage organic agri-startups embedded hi-tech innovations into their supply chains to achieve environmental sustainability. Limited research was on the behavioural dimension of technology adoption, specifically how entrepreneurs prioritised different technologies while navigating sustainability objectives, operational risks, and organisational constraints.

This study addressed these gaps by investigating how hi-tech innovation operated as a key mechanism through which participation in sustainable supply chains translated into environmental improvement and enhanced innovation capacity, thereby filling an important research void in the supply chain and sustainability literature (Gellynck et al., 2006; Weaver, 2008). The study analysed the role of hi-tech innovation in promoting environmental sustainability within organic agri-startups in supply chains, using empirical evidence derived from an Ordinary Least Squares (OLS) model. Furthermore, having adopted a regression-based prioritisation approach, the study revealed that organic agri-startups applied hi-tech tools in a pragmatic manner, to focus on technologies that enhance production processes, ensure compliance with organic standards, and stabilise operations amidst environmental uncertainty. The study empirically assessed the distinct effects of different hi-tech innovations on environmental sustainability within the supply chains of organic agri-startups, and introduced a behavioural decision-making perspective, showing that entrepreneurs' conceptual priorities often diverge from the technologies they actually implement. By integrating insights from sustainability science, startup behaviour, and supply chain innovation, the study shed new light on how resource-constrained organic ventures navigate technology choices while pursuing environmental objectives. These findings enrich theoretical understanding of sustainable and organic entrepreneurship and offer practical guidance for policymakers and ecosystem actors seeking to promote green technological adoption in emerging agricultural sectors.

2. Literature Review

2.1 Organic Agri-Startups and Their Characteristics

Organic agri-startups have increasingly become a key driver in the transition toward ecologically sustainable food systems. These ventures focus on production practices that protect ecosystem functions, promote biodiversity, and maintain long-term soil fertility through natural processes rather than relying on agricultural chemicals (Shubham et al., 2025). Organic agri-startups build on this foundation by integrating entrepreneurial innovation with environmentally grounded farming practices. Organic agri-startups can be understood as early-stage enterprises that produce, process, or distribute organically certified agricultural products using market-oriented and technology-enabled approaches. These startups contribute to enhancing the transparency of supply chains, high-quality organic production, and consumer trust as these are factors increasingly recognized as central to the organic market (Sharma & Subba, 2025; Suresh et al., 2024). By combining ecological farming principles with digital tools and data-driven management, organic agri-startups help improve resource efficiency, enhance traceability, and reduce environmental impacts.

A typical characteristic of organic agri-startups is their clear commitment to environmental sustainability. They employ production approaches that eliminate the use of synthetic pesticides and fertilizers, thus helping to reduce chemical residues, preserve soil microbiota, and avoid water pollution (Gomiero, 2018). Their business models frequently prioritize circular use of resources like recycling nutrients, hence cutting waste and strengthening the resilience of agricultural ecosystems. These startups also foster biodiversity through diversified cropping strategies and ecological pest control, which align closely with the fundamental principles of organic agriculture (Patil et al., 2014). Another essential feature is strict adherence to organic certification and quality standards. Securing certifications provides legitimacy, facilitates market entry, and enables premium pricing. Certification not only reinforces the environmental commitments of these ventures but also guides their internal practices, from soil management to post-harvest processes (Jayakumar & Ezhilvani, 2018).

2.2 Hi-Tech Innovation in Organic Agri-Startups

Innovation refers to the ability of a firm to innovate throughout the entire innovation process (Kühne et al., 2010). 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 research and development (R&D), training, and study tours, which support innovation. Activities involve the actions and processes undertaken to develop and implement these innovations. The outcomes of these activities, as a result, impact both tangible aspects like growth in market share and profits, as well as intangible aspects like stability, efficiency, and reputation of firms.

As regards product and process, organic agri-startups apply technologies such as IoT, AI-driven yield prediction, and resource management tools to enhance farming efficiency, improve crop yields, and enable eco-friendly and organic production. According to Klerkx & Rose (2020), although traditional organic farming emphasized natural processes, these startups increasingly employed digital tools like IoT sensors, remote monitoring, and AI-based disease prediction to optimize production while maintaining organic integrity. These innovations reduce input waste, prevent crop loss, and support environmentally positive outcomes, thus contributing both to productivity and to long-term sustainability. Besides, organic agri-startups integrate governance-oriented technologies such as blockchain and AI to enhance transparency, traceability, and decision making across the supply chain. Blockchain provides secure and immutable records of organic practices, while AI supports planning, resource allocation, and risk management. These tools strengthen compliance with organic and sustainability standards, enabling startups to build consumer trust and maintain high environmental performance (Hasan et al., 2024; Moyo & Assan, 2025). In addition to AI-based predictive tools, the literature suggested that several alternative or complementary technologies could be employed to support decision making and sustainability objectives in organic agri-startups. Rule-based decision support systems, remote sensing technologies, and Geographic Information Systems (GIS) have been widely used to monitor soil conditions, crop health, and land-use efficiency without relying on advanced predictive algorithms (Wolfert et al., 2017). Simulation models and scenario-based planning tools also enable startups to assess production risks, resource allocation, and environmental impacts under different climatic or market conditions, hence offering transparent and interpretable insights that are particularly suitable for resource-constrained firms. Sensor-based monitoring systems, when combined with descriptive analytics and blockchain-enabled traceability, can deliver real-time operational control and environmental accountability in organic agri-startups (Hasan et al., 2024).

Organic agri-startups increasingly use mobile platforms, e-commerce, farm-to-table logistics, and direct-to-consumer sales channels to connect farmers with urban consumers, who are willing to pay a premium for certified organic products. By engaging both customers and suppliers in the innovation process, startups improve market access, reduce dependence on intermediaries, enhance efficiency of supply chains, and maintain organic integrity throughout production and distribution (Sang et al., 2024). These practices also build consumer confidence, as traceable and transparent processes demonstrate commitment to environmental and social responsibility.

For quality and innovation, advanced technologies including nanotechnology, precision farming tools, and yield prediction models drive product quality and operational innovation in organic agri-startups. Data-driven management and smart farming tools optimize resource use, minimize environmental impacts, and ensure consistent and high-quality organic output (Wolfert et al., 2017) Leveraging internal resources such as skilled staff, managerial experience, financial capacity, and networks of supply chains enhances the ability of startups to innovate while remaining competitive (Fielke et al., 2020; Klerkx & Rose, 2020; Kühne et al., 2010).

Overall, these dimensions illustrate how organic agri-startups harness hi-tech innovations not only to improve productivity and operational efficiency but also to strengthen environmental sustainability, transparency of the supply chain, and product quality. By integrating advanced technologies with sustainable supply chain practices, organic agri-startups transform agriculture into a more productive, profitable, and environmentally responsible sector. In this connection, the scaling of organic farming is supported while reinforcing both ecological resilience and economic viability in modern agri-food systems (Gellynck et al., 2006).

2.3 Hi-Tech Innovation and Environmental Sustainability

Several studies examined the impact of integrating into a sustainable supply chain. According to Ashby et al. (2012), a sustainable supply chain incorporated environmental, social, and economic considerations into its management practices to achieve long-term sustainability. Key components included environmental stewardship, social responsibility, and economic viability. Participation in a sustainable supply chain enhances market access and competitiveness. As the demand for sustainably produced goods rises, startups that adopt sustainable practices can tap into this growing market segment, thereby boosting their competitiveness and market reach. Additionally, such practices help startups differentiate their brands, in order to foster customer loyalty and improve brand perception. Sustainable supply chains emphasize resource optimization, which can result in significant cost savings. Adopting energy-efficient technologies and waste reduction strategies can lower operational expenses. Sustainable practices enhance supply chain resilience by promoting diversity and reducing reliance on single sources, to mitigate risks associated with disruptions. Moreover, the increasing focus on environmental, social, and governance (ESG) criteria among investors means that startups with sustainable supply chains are better positioned to attract funding and investment opportunities. Sustainable practices help manage risks related to environmental impacts, such as resource scarcity and climate change, thereby supporting long-term viability.

Recent studies have emphasized that environmental performance in modern supply chains increasingly depends on the integration of hi-tech innovations such as IoT sensors, blockchain traceability systems, AI-based monitoring, and precision agriculture platforms. These technologies enable real-time tracking of energy use, emissions, and resource efficiency, so as to support measurable improvements in environmental sustainability outcomes. Environmental sustainability and digital technologies act as interconnected drivers of business model innovation in the agri-food sector, thus reinforcing each other through enhanced data transparency, digital coordination, and sustainability-oriented value creation. The tensions inherent in this integration such as the push for higher productivity through precision agriculture may sometimes conflict with ecological integrity; the reliance on digital monitoring can challenge perceptions of organic authenticity (Chen & Wang, 2024; Ning & Yao, 2023).

Kühne et al. (2010) highlighted that integrating into sustainable supply chains was gradually recognized as a catalyst for innovation in the agricultural sector. 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 new innovations, such as joint cost management (Weaver, 2008). The supply chain serves as a critical platform where both internal and external resources are combined and transformed into innovative capacities (Gellynck et al., 2006). The outcomes of sustainable supply chain participation are increasingly mediated by the digital and analytical capabilities of firms, particularly in agri-food startups operating under environmental and certification constraints (Wang et al., 2025). By leveraging these resources, agri-startups can become more innovative and achieve a sustainable competitive advantage. A more analytical synthesis of these interactions, highlighting where trade-offs occur, would provide greater theoretical depth and practical guidance for startups navigating complex sustainability challenges. Utilizing complementary capacities and technologies within the supply chain enables startups to address challenges related to the implementation of innovation. Specifically, the application of hi-tech innovation within supply chains provides new mechanisms for environmental improvement. IoT-based field monitoring reduces the overuse of water and fertilizer, blockchain-based certification increases trust and reduces fraudulent inputs, and smart logistics systems minimize transportation-related emissions. As a result, hi-tech adoption is not only an economic or operational choice but also a direct driver of improved environmental sustainability for agri-startups. The agri-food industry confirms that such digital–environmental synergies directly reshape sustainable business models by aligning operational efficiency with ecological performance outcomes (Bruni et al., 2025).

In addition, some studies showed that sustainable supply chains provided startups with access to networks of like-minded partners and stakeholders who prioritized sustainability. This fosters a collaborative environment that enhances knowledge sharing and co-innovation. Tsai & Lasminar (2021) explored how supplier flexibility, supply agility, and company performance were interrelated, while Loon et al. (2018) demonstrated that IT capabilities supported the adoption of supply chain technologies and improved operational performance through partial least squares regression (PLS)-OLS modeling. Fu et al. (2022) used structural equation modeling to show the significant role of sustainable supply chains in accelerating firms' operational and financial performance and suggested that sustainable supply chain management should be integrated with the overall business strategy. Within this context, utilizing hi-tech solutions provides analytical and decision-making advantages. Advanced data analytics, AI-supported demand planning, and digital forecasting tools enhance environmental decision making by reducing waste, matching supply with real demand, and identifying gaps of sustainability more accurately than traditional systems. Acknowledging these synergies and tensions between technological adoption and sustainability goals allows a sharper understanding of strategic trade-offs, thus improving both theoretical and practical insights.

In summary, empirical studies consistently demonstrated a positive relationship between participation in environmentally 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. The relevant literature identified various determinants affecting supply chains, including technology, logistics, market access, collaboration, sustainable practices, and risk management. Some studies have employed various models, such as linear regression, binomial logistic regression, multinomial logit models, and structural equation modeling (SEM), to explore the impacts of sustainable supply chains on innovation and enhance environmental sustainability. However, while many studies addressed these factors and their influence on the effectiveness and innovation of agri-startups, there is a notable gap in research specifically focusing on the impact of sustainable supply chains on hi-tech innovation and environmental sustainability in organic agri-startups in developing countries like Vietnam. Filling this gap, the present study aims to empirically examine the role and prioritisation of hi-tech innovations in promoting environmental sustainability within the supply chains of organic agri-startups, while revealing how entrepreneurs' stated sustainability intentions diverge from their actual choices of technology adoption. Drawing on the existing literature, Figure 1 presents the conceptual framework linking sustainable supply chains, hi-tech innovation, and environmental sustainability in organic agri-startups, with particular attention drawn to the gap between intentions of sustainability and technology adoption practices.

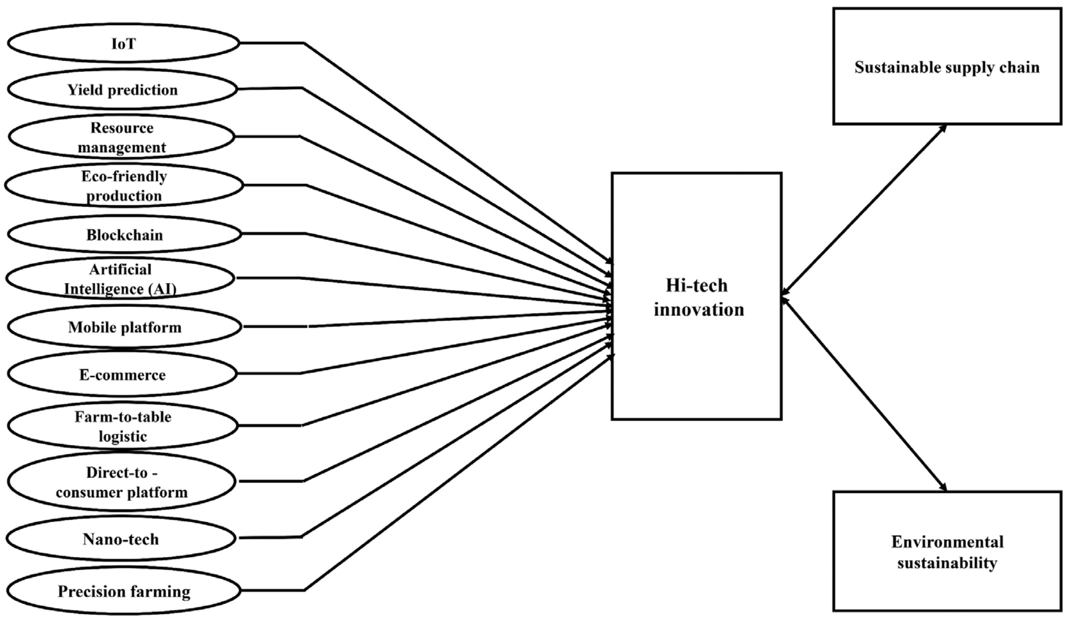

Figure 1. Conceptual framework linking sustainable supply chain, hi-tech innovation, and environmental sustainability in organic agri-startups

3. Methodology

To optimize data collection from agri-startups and encourage their participation in sustainable supply chains, we employed a multistage approach. Initially, we focused on key regions: Ha Nam, Lam Dong, and Dong Thap. These regions were chosen due to their prominence in activities among organic agri-startups in Vietnam. We then randomly sampled 250 registered agri-startups from comprehensive lists provided by local authorities in these areas. Local authorities facilitated interviews at district people's committee offices, where the startups were categorized into production and service groups. Face-to-face interviews were conducted to assess the impact of hi-tech innovation on environmental sustainability. The questions were related to hi-tech innovation, environmental sustainability, and supply chain. Demographic factors such as gender, age, level of education, job, established year, location, and other relevant variables were also covered in the interviews. A total of 250 organic agri-startups were invited to participate in the study, as all of which agreed to engage in an interview examining operational efficiency in innovation within agri-startups and the impact of sustainable supply chains on this innovation.

To assess the impact of joining the supply chain, we also used the OLS regression model to investigate the relationship between hi-tech innovation and environmental sustainability in the supply chains of organic agri-startups. The regression model is appropriate for identifying priority technologies in the context of hi-tech innovation for organic agri-startups, as it accounts for the multifaceted interactions among operational efficiency, environmental performance, and supply chain integration. Through estimating the effects of each hi-tech factor on environmental sustainability outcomes, the model supports evidence-based decision making and helps organic startups and policymakers allocate resources to the most impactful technological solutions. In the regression model, the control variables include age, gender, education level, firm's age, revenue, size of labor, and type of enterprise. The independent variables including IoT, AI, yield prediction technologies, robotics, mobile platforms, and e-commerce capture the core technological domains that shape digital transformation and sustainability enhancement in organic agricultural production systems (see Table 1).

Besides, the study adopted a regression-based prioritisation approach to evaluate the choices of technology and rank high-tech solutions for organic agri-startups. Using this approach, the model estimated the relative impact of each technological factor on sustainability outcomes, including environmental, social, and economic performance. By ranking the standardized coefficients, the study identified the most influential technologies and provided evidence-based guidance for prioritising resource allocation and strategic investments in high-tech solutions. This approach enables decision-makers to simultaneously assess multiple technological dimensions, quantify their relative importance, and support sustainable innovation strategies within organic agri-startups.

Furthermore, demographic and other variables including location, gender, education, business type, years of operation, and revenue, were also incorporated and the factors related to a sustainable supply chain such as technology, logistics and distribution, market access and sourcing, collaboration, sustainability practices, risk management, and strategy were assessed using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1. Operationalization of variables

Factors	Definitions	Indicators	Sources
Environmental sustainability	Minimizing environmental degradation while maintaining ecological balance over the long term.	Environmental sustainability performance	Ashby et al. (2012); Bruni et al. (2025); Chen & Wang (2024); Ning & Yao (2023)
Sustainable supply chain	Incorporating environmental, social, and economic considerations into management practices to achieve long-term sustainability	Environment sustainability Social sustainability Economic sustainability	Ashby et al. (2012); Bruni et al. (2025); Gellynck et al. (2006); Ning & Yao (2023)
Product & process	Applying IoT, yield prediction, resource management, automatic, and eco-friendly production	IoT Yield prediction Resource management Automatic Eco-friendly production	Bruni et al. (2025); Chen & Wang (2024); Klerkx & Rose (2020); Ning & Yao (2023); Wolfert et al. (2017)
Sustainable governance	Using blockchain and AI	AI Blockchain	Bruni et al. (2025); Hasan et al. (2024); Moyo & Assan (2025); Wang et al. (2025)
Customer & supplier	Using mobile platform, e-commerce, farm-to-table logistics, and direct-to-consumer sales platform	Mobile platform E-commerce Farm-to-table logistics Direct-to-consumer sales platform	Ashby et al. (2012); Gellynck et al. (2006); Sang et al. (2024)
Quality & innovation	Applying nano-tech, precision farming, yield prediction	Nano-tech Precision farming Yield prediction	Fielke et al. (2020); Klerkx & Rose (2020); Kühne et al. (2010); Wolfert et al. (2017)

4. Results and Discussions

4.1. Impact of Hi-Tech Innovation on Environmental Sustainability in the Supply Chains of Organic Agri-Startups

As shown in Table 2, standard deviations and minimum–maximum values are reported for all key variables, enabling assessment of variability and data distribution. These descriptive statistics from the survey complement the correlation and regression analyses by clarifying the underlying data structure and supporting the robustness of the empirical results. The owners of agri-startups in the sample have an average age of approximately 34 years, with an average educational attainment of 14 years. The distribution of gender indicates that the sample is predominantly male, with a mean value of 1.46. The enterprises operate across various agricultural sectors, including crop production, livestock, aquaculture, and agricultural services. A mean value of 2.05 suggests a relatively even distribution among business types, with a tendency toward livestock (2) and aquaculture (3). The average operational duration of the enterprises is around 10 years. The average monthly revenue is 400.23 million Vietnamese dong (VND), reflecting that most enterprises generate revenues between 100 and 500 million VND. The average size of workforce is 21.91 employees, indicating that these enterprises are medium-sized within the context of high-tech agriculture. The demographic and enterprise characteristics outlined above reflect the structure and distribution of the sample. Table 2 provides a detailed summary of these characteristics and serves as a basis for analyzing potential relationships between these factors and business performance.

The results of the regression model, as presented in Table 3, elucidated the impact of various innovation factors on the sustainable supply chain of agri-startups in Vietnam. The regression analysis, supported by a significant F-test ($p < 0.05$), confirmed the suitability of the model. All variables showed significant effects with p-values below 0.05. Key factors influencing the integration of sustainable supply chains in agri-startups include eco-friendly production, e-commerce, farm-to-table logistics, resource management, yield prediction, direct-to-consumer sales platforms, blockchain, and nanotechnology. These factors are critical for enhancing environmental sustainability within the agri-startup sector. Consistent with the multidimensional conceptualization of sustainability, Table 3 reports three distinct regression models that correspond to the environmental, social, and economic dimensions of sustainability in the supply chains of agri-startups. Specifically, Model 1 focuses on the outcomes of environmental sustainability, which capture the extent to which green and digital technologies contribute to ecological performance. Model 2 examines social sustainability, emphasizing technologies that enhance labor conditions, decision-making capacity, transparency, and community well-being. Model 3 addresses economic sustainability by assessing how innovation-driven logistics, market access, and digital platforms influence revenue generation and financial performance. This model structure is consistent with the study's conceptual framework, which treats sustainability as a multidimensional construct and allows a systematic comparison of how different technological factors exert differentiated effects across the dimensions of sustainability. Accordingly, the results in Table 3 indicate that different technologies contribute unevenly to sustainability, with eco-friendly production driving environmental outcomes, precision farming strengthening social sustainability, and farm-to-table logistics exerting the strongest economic effects. Green technologies shape environmental performance, precision tools support social well-being, and market-oriented logistics innovations enhance economic sustainability in Vietnamese agri-startups.

Table 2. Descriptive statistics

Characteristic	Descriptions	Mean	S.D.	Min.	Max.
Age	Age of respondent (in year)	34.02	5.925	23	49
Education	Actual schooling years	14.01	0.668	10	16
Gender	1 = Male 2 = Female	1.46	0.664	1	2
Agri-startup types	1 = Crop farming 2 = Livestock production 3 = Aquaculture production 4 = Agricultural services	2.05	0.806	1	4
Region	1 = Ha Nam 2 = Lam Dong 3 = Dong Thap	2.31	0.800	1	3
Years since the establishment of business	Number of years from the time the business was established	10.06	1.572	5	16
Revenue	Monthly revenue (million VND)	400.23	142.700	50	1,712
Labor	Number of labors	21.91	15.400	2	94

Note: S.D. = standard deviation; VND = Vietnamese dong.

Table 3. Impact of hi-tech innovation on environmental sustainability

Variable	Model 1 Environmental Sustainability		Model 2 Social Sustainability		Model 3 Economic Sustainability	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Gender	−0.014	0.027	0.156	0.108	0.089	0.899
Education	−0.081	0.051	−0.078	0.092	−0.091	0.057
Type	0.158	0.070	−0.036	0.102	−0.711	0.085
Labor	−0.006	0.016	−0.053	0.006	−0.002	0.012
Region	0.144	0.062	−0.384	0.082	−0.032	0.062
IoT	0.057	0.093	−0.225	0.024	−0.220	0.019
AI	0.245	0.007	0.023	0.012	0.023	0.017
Yield prediction	0.082	0.081	−0.021	0.017	−0.020	0.081
Automatic	0.123	0.006	0.155	0.004	0.015	0.004
Resource management	0.016	0.002	0.100	0.042	0.100	0.082
Nano-tech	−0.033	0.092	0.113	0.012	0.113	0.012
Eco-friendly production	0.440	0.001	0.039	0.041	0.039	0.011
Mobile platform	0.250	0.014	−0.131	0.002	0.131	0.019
E-commerce	0.223	0.005	0.107	0.032	0.145	0.061
Blockchain	0.269	0.016	0.176	0.001	0.117	0.035
Precision farming	0.096	0.022	0.496	0.065	0.096	0.101
Farm-to-table logistics	−0.093	0.032	0.322	0.002	0.322	0.011
Direct-to-consumer sales platform	0.175	0.031	0.031	0.047	0.031	0.07

Note: Coef. = coefficient; S.E. = standard error.

The findings indicated that technological factors exerted varying degrees of influence on environmental sustainability in the supply chains of Vietnamese agri-startups. Among these factors, eco-friendly production emerged as the strongest driver of environmental sustainability, with an effect size of 0.440, the highest among all variables. This result suggests that environmentally responsible production practices, such as organic fertilizers, reduced chemical inputs, the adoption of bio-based materials, and the implementation of circular waste management, play a central role in mitigating emissions, preserving soil health, and maintaining ecological balance in high-tech agricultural models. These findings align with Müller & Campos (2021), who emphasized that eco-friendly production constituted the most critical determinant of environmental quality improvements in agricultural supply chains.

In addition to eco-friendly production, mobile platforms, blockchain, automation, and e-commerce exhibited positive, albeit more modest, effects on environmental sustainability. Mobile platforms (0.250) and e-commerce

(0.223) might reduce environmental impacts by optimizing communication, lowering transportation needs, and facilitating direct sales from farmers to consumers, thereby decreasing emissions associated with traditional logistics. Blockchain (0.269) enhanced traceability and strengthened farmers' compliance with environmental standards through transparent information flows, consistent with Casino et al. (2019), who highlighted the role of blockchain in promoting ecological accountability across supply chains. Similarly, automation (0.123) helped reduce post-harvest losses and optimized energy use, hence easing pressure on natural resources.

Conversely, several technologies that were typically expected to deliver substantial environmental benefits did not exhibit strong effects in the Vietnamese context. Precision farming showed a positive but relatively modest impact (0.096), despite international evidence demonstrating substantial improvements in input efficiency and resource optimization through advanced data-driven techniques (Liakos et al., 2018). This discrepancy might stem from limited adoption, high investment costs, or inadequate supporting infrastructure. Likewise, the resource management technology factor (0.016) displayed minimal impact, suggesting that water, fertilizer, and energy management systems remained underutilized among agri-startups.

Notably, farm-to-table logistics showed a slight negative effect on the environmental sustainability factor (−0.093), contrary to international studies such as Mastos & Gotzamani (2022). Rather than reducing emissions as commonly expected in localized food systems, this outcome might reflect the use of small-capacity vehicles, high delivery frequency, and limited access to green transportation technologies among Vietnamese organic startups, which collectively increased fuel consumption per unit of product. This finding underscored that shortening physical distance in supply chains did not automatically lead to lower emissions unless accompanied by optimized logistics and investments in cleaner transport solutions.

The findings revealed that several technologies exerted particularly strong influences on the social and economic sustainability of agri-startups. Regarding social sustainability, precision farming factor demonstrated the strongest effect (0.496), significantly surpassing other factors due to its ability to reduce production risks, enhance decision-making capacity, and improve working conditions for farmers. In addition, automation (0.155) and blockchain (0.176) generated notable social impacts by reducing manual labor requirements and increasing transparency within the supply chain, thereby strengthening community and consumer trust. For economic sustainability, technologies associated with market access and logistics exerted the strongest influence. Farm-to-table logistics (0.322) emerged to be the most prominent factor, followed by e-commerce (0.145) and blockchain (0.117). These technologies help reduce intermediary costs, improve market accessibility, and expand distribution channels, thereby enhancing the financial performance of agri-startups. In contrast, production-related technologies such as eco-friendly production and resource management yield relatively modest economic benefits due to high initial investment requirements and longer payback periods.

In comparison with these effects, environmental sustainability was driven most strongly by eco-friendly production factor (0.440), whereas technologies that had prominent social or economic impacts such as farm-to-table logistics or precision farming played only secondary roles in environmental outcomes. This divergence highlights that different groups of technologies promote distinct dimensions of sustainability: green production technologies primarily shape environmental outcomes, precision technologies support social sustainability, and logistics- and market-oriented technologies drive economic performance. Together, these patterns underscore the multidimensional nature of the transition toward sustainable agricultural models.

Although the three models examined different dimensions of sustainability, they shared a common analytical structure by employing the same set of explanatory variables and control characteristics, which ensured comparability across models. However, in Model 1 (environmental sustainability), eco-friendly production exhibited the strongest effect, clearly surpassing other technologies such as blockchain and mobile platforms. In Model 2 (social sustainability), precision farming emerged as the dominant factor, followed by farm-to-table logistics and blockchain, indicating the importance of risk reduction, transparency, and labor-supporting technologies for social outcomes. In Model 3 (economic sustainability), market- and logistics-oriented innovations played a more prominent role, with farm-to-table logistics showing the strongest economic impact, ahead of e-commerce and blockchain. These cross-model differences demonstrated that identical technological innovations generated differentiated sustainability outcomes, hence reinforcing the multidimensional nature of the development of sustainable supply chains in Vietnamese agri-startups.

Overall, the empirical results suggested that environmental sustainability in Vietnamese organic agri-startups remained heavily dependent on production-centered practices, with digital and smart technologies playing a supplementary rather than transformative role. The relatively limited environmental impact of logistics-related innovations highlights structural constraints, including small-scale infrastructure and high-frequency delivery systems. Compared with international evidence (Mastos & Gotzamani, 2022; Müller & Campos, 2021), the Vietnamese context exhibits distinct sustainability pathways shaped by resource constraints and founders' behavior. These findings contribute to the literature by emphasizing the contextual and technology-specific nature of sustainability transitions in the supply chains of agri-startups, to complement existing research on digital supply chains, resilience, and farmer well-being.

4.2. Priority Level of Hi-Tech Innovation in Organic Agri-Startups

The updated findings revealed important behavioural patterns in how organic agri-startups prioritised high-tech innovation. As shown in Table 4, quality and innovation receive the highest weighting (0.45), followed by customer and supplier management (0.31), product and process (0.30), and sustainable governance (0.27). This result highlighted that the actual technological decisions of organic argi-startups were driven primarily by the operational needs of production and process improvement.

Table 4. Priority ranking of technology in agri-startups

Factor	Standardized *β*	Rank
Product and process	0.30	3
Sustainable governance	0.27	4
Customer and supplier management	0.31	2
Quality and innovation	0.45	1

The prioritisation results were derived from the relative magnitude of standardized regression coefficients, which indicated the comparative influence of each technological factor on sustainability outcomes. This finding suggests that organic agri-startups tend to prioritise technologies that directly enhance product quality, innovation capacity, and supply chain relationships over broader governance-related technologies. Technological prioritisation in organic agri-startups is driven primarily by operational efficiency and innovation-oriented considerations, thus reflecting the immediate production and market demands faced by these enterprises. This behavioural tendency is further mirrored in the prioritisation of IoT and automation, which are consistently ranked highest by both experts and startup founders. Organic agri-startups tend to favour technologies that deliver immediate operational benefits of greater efficiency, real-time monitoring, and enhanced traceability because these tools directly reduce uncertainty and strengthen managerial control throughout organic production systems. This corresponds with Casino et al. (2019), who emphasised that IoT enhanced supply chain sustainability by reducing waste, increasing transparency, and improving responsiveness. Automation likewise addresses labour shortages and improves consistency in cultivation, harvesting, and post-harvest activities that are especially labour intensive in organic farming.

After IoT and automation, entrepreneurs show continued interest in AI and yield-prediction systems, which support decisions under climatic stress and production variability. These technologies enable climate monitoring, risk anticipation, and adaptive responses to extreme events, thus helping organic startups safeguard production stability and supply chain continuity. This behaviour aligns with the strategic mindset of organic entrepreneurs, who must constantly manage ecological uncertainty while adhering to strict production standards. In contrast, mobile platforms and e-commerce are assigned lower priority, as organic entrepreneurs view them as less essential to core production activities or face adoption barriers such as limited connectivity and digital skills. This indicates a clearly production-first behavioural tendency, in which technologies that directly enhance productivity, quality, and risk reduction are adopted before market-oriented digital tools.

Building on these behavioural insights, the results of regression-based prioritisation quantitatively confirm that IoT and automation have the strongest impact on enhancing environmental and operational performance in organic agri-startups, followed by AI and yield-prediction systems. This ranking aligns with the qualitative observations from founders and experts, in order to demonstrate a clearly production-first strategy (Casino et al., 2019; Ning & Yao, 2023). These findings are consistent with prior literature by indicating that digital and smart technologies not only improve traceability, efficiency, and responsiveness but also facilitate compliance with sustainability standards in agricultural supply chains (Bruni et al., 2025; Chen & Wang, 2024). Conversely, mobile platforms and e-commerce, while important for market engagement, exhibit lower direct influence on operational and environmental outcomes, thus highlighting a gap between market-oriented digital tools and core production technologies (Wang et al., 2025). Overall, the results emphasize that technology adoption in organic agri-startups is strategically aligned with operational stability, risk mitigation, and environmental stewardship, in order to reinforce the multidimensional role of high-tech innovations in sustainable agricultural practices.

5. Conclusions

This study addressed existing gaps by examining the role of hi-tech innovation in enhancing environmental sustainability in the supply chains of organic agri-startups, using empirical evidence from an OLS model based on a sample of 250 organic agri-startups in Vietnam. The results indicated that environmental performance was most strongly driven by eco-friendly production (0.440), followed by blockchain (0.269) and mobile platforms (0.250). Moreover, through a regression-based prioritisation analysis, the study discovered that organic agri-startups adopted hi-tech solutions pragmatically, to prioritise technologies that strengthen production processes, ensure compliance with organic standards, and stabilise operations under environmental uncertainty. The findings of this study carry several implications across political, practical, and social dimensions. Government policies and incentives promoting eco-friendly production, digital technologies, and sustainable logistics could accelerate the adoption of high-impact innovations in agri-startups. Supporting infrastructure for precision farming, farm-to-table logistics, and blockchain implementation, alongside financial incentives for small and medium-sized enterprises, could strengthen environmental and economic outcomes. The need for organic agri-startups to strategically prioritize technology investments such as green production practices should be emphasized for environmental gains, precision farming for social well-being, and logistics or e-commerce solutions for economic performance. Besides, the study underscores the potential of technological adoption to improve labor conditions, community engagement, and consumer trust, particularly through transparency-enhancing tools such as blockchain and automation. In general, this study confirms that the performance of sustainable supply chain in Vietnamese organic agri-startups is multidimensional and technology-dependent. Eco-friendly production emerges to be the primary driver of environmental sustainability, while precision farming and automation enhance social outcomes, and logistics-focused innovations optimize economic performance. The findings extend the literature by demonstrating the differentiated impact of technological factors on sustainability dimensions and by emphasizing the behavioural tendencies of founders toward production-centric innovations. These findings therefore highlight several implications for practice and policy:

Firstly, government policies play a crucial role in promoting the adoption and development of hi-tech solutions in organic agri-startups. By providing financial support, fostering research and development, building infrastructure, offering education and training, establishing clear regulations, facilitating market access, and promoting sustainability, governments could create an enabling environment that enhances efficiency, productivity, and sustainability in the agricultural sector. Specific measures include grants and subsidies for agri-startups implementing sustainable practices such as organic farming, renewable energy, and water conservation technologies.

Secondly, organic agri-startups should adopt strategic approaches to foster innovation and integrate sustainability into their operations. Governments and stakeholders could support these strategies through targeted policies, including: financial incentives for research and development and advanced technology adoption, government-backed venture capital funds to reduce investment risk, investments in rural infrastructure, technical assistance for sustainable farming practices, and simplified regulatory and certification processes.

Thirdly, support for eco-friendly production could be enhanced through financial and educational measures. Governments could provide grants, tax incentives, and subsidies for eco-friendly production methods, alongside training programs to educate producers, manufacturers, and supply chain managers on the benefits and implementation of sustainable practices.

Fourthly, improving technological accessibility and lowering adoption barriers is essential. Investments in rural digital infrastructure such as stable internet connectivity, cloud-based storage, and affordable smart sensors are critical to enable widespread adoption of IoT, AI, and other digital tools.

Nevertheless, the study has certain constraints, such as focusing exclusively on organic agri-startups in Vietnam, and some technological factors, including resource management systems and precision farming, hence showing limited adoption, which may bias the observed sizes of effect. For future research, studies examining cross-regional or farm-size comparisons may uncover context-specific constraints or opportunities. Furthermore, integrating qualitative behavioural insights, such as risk perception, entrepreneurial mindset, and attitudes toward technology, with quantitative decision models could provide a thorough understanding of the drivers and challenges of hi-tech adoption in organic agri-startups.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The author declares no conflicts of interest.

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