

OPTIMIZATION OF RICE SUPPLY CHAIN MANAGEMENT TO IMPROVE EFFICIENCY AND FOOD SECURITY

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ABSTRACT

Rice supply chain management has a crucial role in improving distribution efficiency and supporting food security. This study aims to analyze factors that affect the effectiveness of the rice supply chain, including production factors, distribution and logistics efficiency, market and economic factors, government policies, and the application of technology and digitalization. Using the *Structural Equation Modeling (SEM)* method, the results show that only *the Distribution & Logistics* and *Policy & Regulation factors* have a significant influence on the effectiveness of the rice supply chain. Distribution and logistics efficiencies that include transportation, warehousing, and supply chain coordination are proven to improve smooth supply and reduce distribution costs. Meanwhile, government policies such as subsidies and import-export regulations play a role in maintaining price stability and ensuring the availability of rice for the community. On the contrary, production factors, market and economic factors, as well as the application of technology and digitalization did not show significant influence in this study. Therefore, a strategy to improve logistics infrastructure and harmonize government policies is needed to ensure the sustainability of a more efficient and competitive rice supply chain.

Keywords: *Rice supply chain, logistics efficiency, government policy, food security, SEM-PLS*

INTRODUCTION

Optimal rice supply chain management is essential in improving efficiency and maintaining food security. Rice is a staple for most of the world's population, especially in developing countries such as Indonesia. However, the rice supply chain often faces a variety of challenges, including inefficiencies in production and distribution, price fluctuations, and the environmental impact of agricultural and logistics processes. Therefore, supply chain optimization strategies and models continue to be developed to improve efficiency while ensuring the sustainability of the agricultural sector.

Problems in rice supply chain management are crucial issues in the agriculture and food sector because they involve various aspects that affect quality, efficiency, and supply sustainability. The complex rice supply chain includes many parties, from farmers, millers, distributors, to end consumers, who often face challenges in information management, coordination, and quality control. This complexity can lead to inefficiencies in distribution and risk disrupting a country's food security (Jamaludin et al., 2021; Peng et al., 2022). For example, in Thailand, the organic rice supply chain is constrained due to a lack of efficient equipment, high transportation costs, and high production costs that have an impact on the selling price and competitiveness of products (Pakdeenarong & Hengsadeeikul, 2020).

In addition to the complexity of the supply chain, rice quality and safety issues are also a major challenge. Lack of good information management and weak quality control systems can lead to poor rice quality, contamination, and potential negative impacts on public health (P. Kumar, 2024; Peng et al., 2022). This problem is further exacerbated by inadequate storage, pest attacks,

and changes in the moisture content of rice which can result in waste and losses for farmers and traders.

Another challenge in the rice supply chain is the limitation of infrastructure and logistics efficiency. Rice distribution requires a good transportation and warehousing system so that the supply can be distributed smoothly and costs remain under control. However, in many areas, poor road infrastructure, lack of adequate modes of transportation, as well as inefficient warehousing systems lead to increased logistics costs and delays in distribution. This not only has an impact on the price of rice that is more expensive for consumers, but also reduces profits for farmers due to the length of the distribution chain and additional costs that must be borne by farmers.

Rice price instability is also a major challenge in the supply chain. Rice prices are greatly influenced by fluctuating demand and supply factors due to climate change, natural disasters, or market speculation. This makes it difficult for farmers to plan their production and income. In some countries, government policies have an important role in controlling prices and maintaining national food stability. However, improper policies, such as unbalanced import regulations or inefficient distribution of subsidies, can actually exacerbate problems in the rice supply chain (P. Kumar & Yasmeen, 2021).

In addition, the limitations of technology adoption in the rice supply chain are still an obstacle in increasing efficiency. While digital technologies and smart supply chain models have great potential to increase transparency and efficiency, their implementation is still hampered by the lack of digital infrastructure and the low understanding of the benefits of these technologies. Blockchain technology, for example, can improve information surveillance in the rice supply chain by providing a secure and efficient system for managing data, but its application is still limited in many countries (M. Kumar & Iyengar, 2017; Wang et al., 2024). Meanwhile, the smart supply chain model that integrates digital systems to predict market demand, optimize distribution, and reduce production costs is still rarely applied in the agricultural sector (Li et al., 2024a; Perdana et al., 2020), so it is necessary to optimize the rice supply chain.

One of the key strategies in rice supply chain optimization is the implementation of a multi-objective model that integrates food, energy, and chemical production. Studies conducted in the Philippines show that this approach is able to increase agricultural productivity and reduce greenhouse gas emissions by 25% and 24%, respectively (Doliente & Samsatli, 2020; Kurniawati, 2020). In addition, the implementation of efficient supply chain management has been proven to increase production and the ratio of rice demand fulfillment. For example, in Demak Regency, a more optimal supply chain model has succeeded in increasing the fulfillment of rice needs by 12% and reducing logistics costs by 14.3%, as well as reducing rice prices by 3.75% (Kurniawati et al., 2020).

In addition to production and distribution efficiency, sustainability in the rice supply chain is also a key focus. In Nigeria, the implementation of sustainable practices such as more efficient water use and supplier diversification is able to improve food security. However, government intervention and improved quality assurance are still needed to encourage better productivity (Bello & Mbhele, 2024). The application of digital technology also has an important role in improving supply chain efficiency. In Jilin Province, the integration of digital technologies such as internet-based models and modern agricultural services has been proven to be able to improve production efficiency and resource allocation, thus making the rice supply chain more resilient and profitable (Li et al., 2024b). The application of advanced technologies such as blockchain and machine learning can increase transparency and efficiency in the rice supply chain. Blockchain

ensures more secure and transparent transactions, while machine learning helps in assessing grain quality and predicting crop yields more accurately (Ahila et al., 2024).

Thus, rice supply chain optimization requires a holistic approach, starting from the implementation of production integration models, efficiency in distribution, adoption of sustainable practices, to the use of digital technology and blockchain. The combination of these strategies is expected to increase efficiency, reduce costs, and ensure long-term food security in various regions. The purpose of this study is to analyze the factors that affect the effectiveness of the rice supply chain using a quantitative approach. In particular, this study aims to examine the influence of production factors, distribution and logistics efficiency, market and economic factors, government policies, as well as the application of technology and digitalization on the effectiveness of the rice supply chain. By understanding the relationship between these variables, this study is expected to provide strategic recommendations to improve the efficiency, resilience, and sustainability of the rice supply chain in Indonesia.

METHOD

This study uses a quantitative approach with statistical analysis methods to measure the effectiveness of the rice supply chain in Yogyakarta Province. The model used is *Structural Equation Modeling - Partial Least Squares* (SEM-PLS), which allows the analysis of relationships between latent variables in the supply chain system. The data used in this study is data on the rice supply chain in the DI Yogyakarta Province area during the period from September to December 2024. Data is collected from various stakeholders in the supply chain, including farmers, distributors, retailers, and end consumers. The variables used in this study are based on factors that affect the effectiveness of the rice supply chain as identified in previous studies. Key variables include:

- Production: Agricultural inputs, farming techniques, climate conditions, land productivity
- Distribution & Logistics: Transportation, warehousing, supply chain coordination
- Market & Economy: Price fluctuations, demand and supply balance, international trade
- Policy & Regulation: Government policies, subsidies, import-export regulation
- Technology & Digitalization: Precision farming, supply chain tracking, data analytics

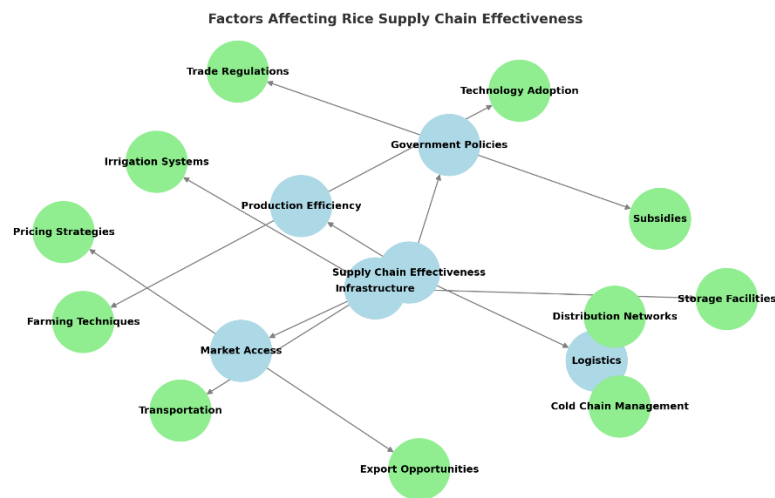
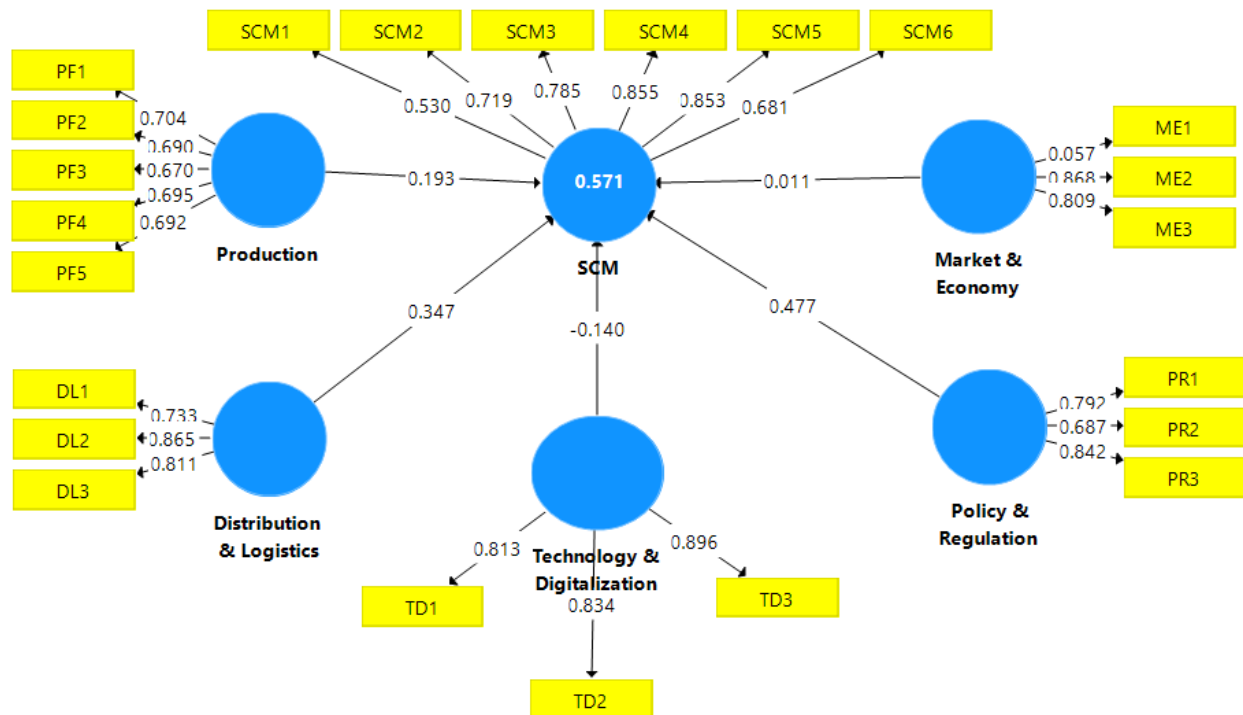


Figure 1. SCM research variables

Primary data were collected through surveys and interviews with rice supply chain stakeholders. Meanwhile, secondary data is obtained from government reports, academic publications, and statistical data related to rice production and distribution. Data analysis was carried out using the SEM-PLS method with the help of software such as SmartPLS or WarpPLS. Using the following hypothesis:

- **H1:** Production factors (seed availability, agricultural technology, climate, land, and infrastructure) have a positive effect on the effectiveness of the rice supply chain.
- **H2:** Distribution and logistics efficiency (transportation, warehousing, and supply chain integration) have a positive effect on the effectiveness of the rice supply chain.
- **H3:** Market and economic factors (price, competition, and consumer demand) have a positive effect on the effectiveness of the rice supply chain.
- **H4:** Government policies (subsidies, import/export policies, and standardization) have a positive effect on the effectiveness of the rice supply chain.
- **H5:** The application of technology and digitalization (IoT, blockchain, e-commerce) has a positive effect on the effectiveness of the rice supply chain.

RESULTS AND DISCUSSION



Gmabar 1. Model SEM SCM

The model image displaying the loading factor value shows that all indicators have values that meet the convergence validity standard, which is above 0.5 (Ghozali, 2014). This indicates that each indicator is able to represent a well-measured construct. In addition, Cronbach's Alpha and

Composite Reliability (CR) values are also above the minimum limits of 0.6 and 0.7, which confirms that this research instrument has a high level of reliability. The Average Variance Extracted (AVE) value that exceeds 0.5 further strengthens the conclusion that this model has passed the validity and reliability test. Therefore, the results of this measurement can be used for further analysis related to the effectiveness of the rice supply chain.

Tabel 1. Construct Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Distribution & Logistics	0,728	0,748	0,846	0,648
Market & Economy	0,582	0,589	0,826	0,704
Policy & Regulation	0,672	0,696	0,819	0,603
Production	0,637	0,653	0,804	0,580
SCM	0,846	0,862	0,890	0,621
Technology & Digitalization	0,807	0,844	0,885	0,719

Source: Primary Data Analysis

The results of the validity and reliability tests show that all variables in the model have met the required standards, so that they can be used for further analysis. The reliability of the construct can be seen from the Cronbach's Alpha value which is above 0.6 on all variables, indicating that the research instrument has a fairly good internal consistency (Ghozali, 2018). In addition, a Composite Reliability (CR) value of more than 0.7 confirms that each construct has high reliability in measuring the concept in question. In terms of convergence validity, the Average Variance Extracted (AVE) value for all variables is more than 0.5, indicating that each construct is able to explain more than 50% of the variance of the indicator. Thus, the model used has good measurement quality and is reliable in assessing the effectiveness of the rice supply chain.

Tabel 2. Fornell-Larcker Criterion

	Distribution & Logistics	Market & Economy	Policy & Regulation	Production	SCM	Technology & Digitalization
Distribution & Logistics	0,805					
Market & Economy	0,481	0,839				
Policy & Regulation	0,523	0,691	0,776			
Production	0,579	0,382	0,380	0,761		
SCM	0,635	0,485	0,659	0,450	0,788	
Technology & Digitalization	0,661	0,619	0,686	0,551	0,521	0,848

Source: Primary Data Analysis

Based on the results of the Fornell-Larcker Criterion, this research model has met the validity test of discrimination. The validity of discrimination is said to be satisfied if the square root of the Average Variance Extracted (AVE) (the value of the table's diagonal) is greater than the correlation between constructs (the value outside the diagonal). In the table, all diagonal values are higher than the correlation values between variables, which indicates that each construct is

stronger at explaining its own variable than the other variables. Thus, these results indicate that each variable in the study has good discriminatory validity, so that the model used can be trusted for further analysis related to the effectiveness of the rice supply chain.

Table 3. Model fit

	Saturated Model	Estimated Model
SRMR	0,090	0,090
d_ULS	1,549	1,549
d_G	0,740	0,740

Source: Primary Data Analysis

Based on the table shown, several indicators are used to assess the model fit in the Structural Equation Modeling - Partial Least Squares (SEM-PLS) analysis. An SRMR (Standardized Root Mean Square Residual) value of 0.090 indicates that the level of mismatch between the observed and predicted covariance matrix is still within acceptable limits, although it is more ideal if the value is below 0.08. The d_ULS (Squared Euclidean Distance) indicator with a value of 1.549 and d_G (Geodesic Distance) of 0.740 measures the extent to which the model is in accordance with empirical data based on the distance approach. Lower values indicate a better match. In this case, although not too bad, the results show that the model can be improved to achieve a more optimal fit. Overall, the model has a fairly good level of conformity, but there is still room for improvement to improve its accuracy and validity.

R square

Tabel 4. R square

	R Square	R Square Adjusted
SCM	0,565	0,542

Source: Primary Data Analysis

The R Square (R^2) value of 0.565 for the Supply Chain Management (SCM) variable shows that 56.5% of the variation in SCM can be explained by independent variables in the research model. Meanwhile, the Square Adjusted R value of 0.542 indicates the adjusted R^2 value based on the number of variables in the model, which means that about 54.2% of the SCM variation can still be explained after adjusting for the number of predictors used.

An R^2 value close to 1 indicates a good model in explaining the relationship between independent variables and SCM, while a lower value indicates that there are other factors outside the model that affect SCM. With an R^2 value of 0.565, this model has a strong predictive power in explaining the effectiveness of rice supply chain management.

Table 5. Hypothesis Test

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Distribution & Logistics -> SCM	0,361	0,330	0,117	3,083	0,002
Market & Economy -> SCM	-0,017	0,012	0,099	0,172	0,864
Policy & Regulation -> SCM	0,520	0,503	0,098	5,299	0,000
Production -> SCM	0,190	0,207	0,108	1,755	0,080

Technology & Digitalization -> SCM	-0,177	-0,168	0,102	1,730	0,084
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Source: Primary Data Analysis

H1: Production factors have a positive effect on the effectiveness of the rice supply chain

The original sample value of 0.190, T-Statistics 1.755, and P-Value 0.080 showed that production factors did not have a significant effect on the effectiveness of the rice supply chain. Although production factors such as seed availability, agricultural technology, climate, land, and infrastructure have a positive relationship with supply chain effectiveness, the results of the analysis show that the influence is not strong enough or significant in this model.

H2: Distribution and logistics efficiency has a positive effect on the effectiveness of the rice supply chain

The original sample value of 0.361, T-Statistics 3.083, and P-Value 0.002 showed that distribution and logistics efficiency had a significant influence on the effectiveness of the rice supply chain. In other words, the better the transportation, warehousing, and integration systems in the supply chain, the higher the effectiveness of rice supply chain management. This shows that increased efficiency in logistics can help reduce costs, speed up distribution, and improve supply stability.

H3: Market and economic factors have a positive effect on the effectiveness of the rice supply chain

The original sample value of -0.017, T-Statistics 0.172, and P-Value 0.864 showed that market and economic factors did not have a significant influence on the effectiveness of the rice supply chain. This means that the price, competition, and consumer demand variables in this model do not directly increase the effectiveness of the supply chain. While economic factors are important in the food system, there are likely to be other factors that are more dominant in determining the effectiveness of the rice supply chain.

H4: Government policies have a positive effect on the effectiveness of the rice supply chain

The original sample value of 0.520, T-Statistics 5.299, and P-Value 0.000 show that government policies have a very significant influence on the effectiveness of the rice supply chain. In other words, policies related to subsidies, import/export regulations, and rice standardization contribute greatly to improving the efficiency and sustainability of the rice supply chain. The right policies can help maintain price stability, ensure supply availability, and increase the competitiveness of farmers and business actors in the rice sector.

H5: The application of technology and digitalization have a positive effect on the effectiveness of the rice supply chain

The original sample value of -0.177, T-Statistics 1.730, and P-Value 0.084 show that the application of technology and digitalization have no significant influence on the effectiveness of the rice supply chain in this model. While technologies such as IoT, blockchain, and e-commerce have great potential to improve efficiency and transparency in the supply chain, uneven implementation or challenges in technology adoption may be the reason why these variables have not shown significant impact in this research model.

Hypothesis 1 was not accepted because production factors did not have a significant influence on the effectiveness of the rice supply chain (P-Value = 0.080). This may be due to limited infrastructure, dependence on climatic conditions, and limited access to agricultural

technology in some areas. Hypothesis 3 was also not accepted because market and economic factors did not have a significant effect on the rice supply chain (P-Value = 0.864). Rice prices and demand tend to be more influenced by government policies than by free market mechanisms, so that the impact of economic factors becomes less dominant. Hypothesis 5 is rejected because the application of technology and digitalization have not had a significant impact on the effectiveness of the supply chain (P-Value = 0.084). Low technology adoption, limited digital infrastructure, and high implementation costs are the main obstacles in the implementation of digital-based solutions in the agricultural and rice distribution sectors.

Several studies show that production, market, and technology factors do not always have a significant effect on the effectiveness of the rice supply chain. For example, a study in Perum BULOG Sub Division Regional IV Banyumas found that the level of market integration in the rice supply chain is very low, with a correlation coefficient between 0.171 to 0.242, indicating that there is no perfect market integration. In addition, research at the Toko Tani Indonesia Center in Gorontalo City shows that the rice supply chain has three main flows—product, money, and information—and has been running well, but does not specifically highlight the role of production, market, or technology factors in the effectiveness of the supply chain. These findings suggest that the influence of these factors may vary depending on the context and location of the study (Pryabowo, 2019; Syukur et al., 2024).

Two factors that have a significant impact on the effectiveness of the rice supply chain are Distribution & Logistics and Policy & Regulation. The research is in line with the fact that distribution and logistics play an important role in rice supply chain management in Indonesia, with logistics costs reaching 21-23% of GDP, higher compared to other developing countries (Prabowo & Pudjianto, 2023). Transportation and inventory costs are the largest components in this cost structure, which ultimately has an impact on rice prices at the consumer level. Distribution efficiency is also a challenge because the rice supply chain involves many intermediaries, including middlemen, grinders, and wholesalers, which often leads to inefficiencies in distribution flows and pricing (Guritno et al., 2021; Octania, 2021). In addition, Indonesia's geographical condition consisting of many islands further complicates rice distribution, so programs such as the Sea Toll and public service obligations (PSO) have not been fully successful in reducing price disparities in various regions (Prabowo & Pudjianto, 2023).

Government policies and regulations have a major influence on the rice supply chain, especially in terms of subsidies, import-export regulations, and tax and transportation policies. Bulog's role as an institution responsible for stabilizing rice prices and supply also faces challenges in its implementation (Octania, 2021). Therefore, a more integrated strategy is needed to improve logistics efficiency and reduce distribution costs, such as infrastructure optimization, improved coordination in the supply chain, and more flexible and adaptive policies. With a more collaborative approach between the government and industry players, the rice supply chain can become more efficient, thereby supporting food security and ensuring more stable prices for the community (Jamaludin et al., 2021).

The following is a strategy for optimizing rice SCM in supporting national food security:

1. Distribution & Logistics

These factors include transportation, warehousing systems, and efficient supply chain coordination. Good transportation infrastructure speeds up rice distribution, reduces logistics costs, and minimizes crop losses due to delays in delivery. Modern warehousing systems also play a role in maintaining the quality of rice and reducing the risk of damage due to suboptimal

storage. Good coordination between stakeholders, such as farmers, distributors, and traders, ensures that the supply of rice remains stable in various regions.

Strategy:

- Increase investment in transportation and warehousing infrastructure.
- Developing digital-based tracking and supply chain management technology.
- Strengthen coordination between farmers, mills, and distributors to reduce bottlenecks in distribution.

2. Policies & Regulations

The role of the government is very important in stabilizing the rice market through subsidy policies, import-export regulations, and quality standardization. The basic rice price policy and subsidies for farmers can ensure the sustainability of production and the welfare of farmers. Import-export regulations also affect the balance of domestic supply, prevent price spikes, and protect local production. Rice quality standardization helps increase competitiveness in domestic and international markets.

Strategy:

- Providing fertilizer and seed subsidies to farmers to increase productivity.
- Regulating rice import policies so as not to harm local farmers.
- Setting national rice quality standards to increase competitiveness and market confidence.

These two factors play a major role in supporting food security by ensuring that the supply of rice is available, affordable, and of high quality for the community.

CONCLUSION

Based on the results of the analysis, only *the Distribution & Logistics* and *Policy & Regulation factors* have a significant influence on the effectiveness of the rice supply chain. Distribution and logistics efficiency play a crucial role in ensuring smooth supply, reducing costs, and improving rice accessibility. Meanwhile, government policies, including subsidies and import-export regulations, play a role in maintaining price stability and ensuring the availability of rice for the community. In contrast, production, market and economic factors, as well as technology and digitalization did not have a significant impact on the effectiveness of the supply chain in this study, which may be influenced by specific conditions in the field, limitations in technology adoption, or other variables that have not been studied in depth.

Research Implications

To improve the effectiveness of the rice supply chain and support food security, several strategies can be implemented. The government and industry players need to strengthen logistics infrastructure, such as the construction of a more efficient transportation network and the optimization of warehousing systems. In addition, policy harmonization between the central and regional governments is needed to reduce bureaucratic obstacles and improve distribution efficiency. In the long term, although technology has not shown significant impact, digitalization efforts must still be encouraged through farmer training and the integration of data-driven technologies to improve the transparency and efficiency of supply chains in the future.

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