

Holistic Effects of Supply Chain Digitalization on the Sustainability of Food MSMEs: Evidence from a PLS-SEM Hierarchical Model in Padang

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Abstrack - This study examines the effect of supply chain digitalization on the sustainability of food micro, small, and medium enterprises (MSMEs) in Padang, Indonesia. Sustainability is conceptualized as an integrated construct comprising economic, social, and environmental dimensions. A quantitative research design was employed using survey data collected from 50 food MSMEs, which were analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS 3.0. The results show that supply chain digitalization has a significant positive effect on sustainability when assessed holistically, whereas its direct effects on the economic, social, and environmental dimensions individually are not statistically significant. These findings indicate that the contribution of digitalization to MSME sustainability is realized through an integrated mechanism rather than through isolated sustainability dimensions. Theoretically, this study contributes to literature by reinforcing the importance of a holistic sustainability perspective in explaining the impact of supply chain digitalization. Practically, the findings provide insights for policymakers and MSME practitioners to promote integrated digital adoption strategies that support long-term sustainable performance.

Keywords: Digitalization, Supply Chain, Sustainability, PLS-SEM, MSMEs

I. INTRODUCTION

Micro, small, and medium enterprises (MSMEs) of food are one of the important pillars in the regional economy in Padang. Based on data from the West Sumatra Provincial Industry and Trade Office (2023), there are more than 7,500 units of food MSMEs spread across various districts/cities, and this sector makes a significant contribution to the absorption of local labor and the increase in the Gross Regional Domestic Product (GDP) of the processing industry. In addition to their economic role, food MSMEs also contributes to the preservation of Minangkabau culinary specialties, which have high cultural value and strong competitiveness in the domestic and international markets. However, in the face of the digital era and global value chain dynamics, food MSMEs are still faced with various challenges in maintaining business sustainability, which include economic (efficiency and profitability), social (welfare of workers and local communities), and environmental (waste management and efficient use of resources). The complexity of these challenges increases along with changing consumer preferences that demand faster, more transparent, and digital-technology-based services. In addition, many MSMEs have not been able to manage the supply chain optimally, starting from raw material procurement, inventory management, production processes, and product distribution [Kurniawan dan Kusumawardhani, 2021].

Supply chain digitalization is one of the strategic approaches that continues to develop in an effort to increase the competitiveness of MSMEs. The use of technology such as cloud-based inventory systems, local e-commerce platforms, GPS-based distribution tracking, and MSME-scale ERP applications is believed to

improve operational efficiency, minimize waste, and encourage sustainable value-added creation. [Z dan Ghazali, 2024]. In addition, the report [Sohnius et al, 2023]It shows that supply chain digitalization has the potential to reduce operational costs by up to 30% and accelerate demand fulfillment by around 40%, especially in the food and beverage sector in developing countries. Another study states that operational digitalization has a significant effect on improving the sustainable performance of MSMEs, especially when integrated with a collaborative and transparent supply chain system. [B dan Susanto, 2025].

From a theoretical perspective, the relationship between supply chain digitalization and sustainability dimensions is not always direct or immediate. Digitalization primarily serves as an enabling mechanism that enhances information transparency, coordination, and integration across supply chain activities. In the context of MSMEs, improvements in economic performance, social responsibility, or environmental practices often depend on complementary organizational capabilities, managerial readiness, and integrated implementation strategies. As a result, digitalization may not directly influence each sustainability dimension independently but instead contributes to sustainability through a holistic and systemic process [Tobing dan Nugroho, 2024]. This perspective supports the conceptualization of sustainability as an integrated construct and provides a theoretical explanation for why the overall effect of supply chain digitalization on sustainability is stronger than its direct effects on individual dimensions.

However, the adoption rate of digital technology in food MSMEs in Padang is still relatively low. This condition is influenced by limited infrastructure, low digital literacy of business actors, and a lack of policy support and technical assistance. In addition, research that discusses conceptually and empirically the

contribution of supply chain digitalization to the sustainability of food MSMEs in this region is still very limited. This study uses a quantitative approach through a survey of MSMEs and the use of secondary data from related agencies. The results of this research contribute theoretically to developing the MSMES digitalization model and become a practical reference for local governments and industry players in encouraging sustainable digitalization.

II. RESEARCH METHODOLOGY

2.1. Hypothesis Formulation

Based on the research objectives stated above, the hypotheses of this study are formulated as follows:

H1: Supply chain digitalization has a positive effect on the sustainability of MSMEs in Padang.

H1a: Supply chain digitalization has a positive effect on the economic aspect.

H1b: Supply chain digitalization has a positive effect on the social aspect.

H1c: Supply chain digitalization has a positive effect on the environmental aspect.

2.2. Indicator Identification

At this stage, the initial step undertaken is the identification of all indicators related to supply chain digitalization and sustainability aspects. The first activity involves a systematic review of indicators relevant to the concepts of supply chain digitalization and sustainability. These indicators are identified, adapted, and refined based on various sources of scientific literature. Subsequently, indicators that are not aligned with the actual conditions of small and medium-sized industries are screened and excluded from the list. This filtering process aims to eliminate indicators that are irrelevant to the focus and context of the study.

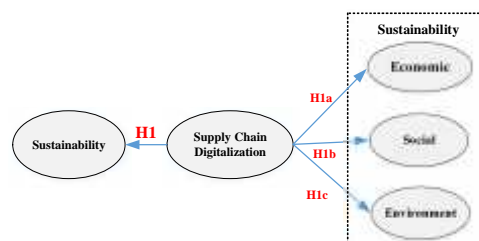


Figure 1. Hypothesis

Furthermore, indicators and dimensions that share similar meanings or conceptual definitions are integrated and grouped into unified indicators or dimensions. This process of merging and classification is conducted to ensure conceptual clarity, reduce redundancy, and establish a coherent structure of indicators and dimensions used in the analysis.

2.3. Data Collection Techniques

Data collection was conducted through the distribution of questionnaires administered both in person and online (via Google Forms) to MSMEs in Padang, with a total of 50 respondents. According to Ghazali, (2021) In the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach, the minimum recommended sample size ranges from 30 to 100 respondents. The determination of the sample size may also follow a rule of thumb, which suggests that the minimum number of samples should be ten times the number of endogenous latent variables included in the research model. Based on the research model, there are only four endogenous latent variables, namely economic, sustainability, environment, and social. Therefore, referring to the PLS-SEM rule of thumb, the minimum required number of respondents is 40. The questionnaire consisted of respondent demographic information and assessed MSMEs of the research indicators, which were rated using a five-point Likert scale. Data collection was carried out over the period from July to November 2025.

2.4. Data Processing

Data analysis was conducted using the PLS-SEM (Partial Least Squares–Structural Equation Modeling) method with the assistance of SmartPLS 3.0 software. The data processing procedure comprised several stages. First, model conceptualization was performed to define the latent variables and their relationships based on the research framework. This was followed by the development of a path diagram to visually represent the proposed structural relationships among the constructions. Subsequently, the measurement model and structural model were evaluated to assess reliability, validity, and the strength of the relationships between variables. Finally, hypothesis testing was carried out to examine the significance and direction of the

proposed effects. The PLS-SEM method was chosen because it can test predictive relationships between variables without the need for strong theories or big data, offers high flexibility in connecting theories and data, can analyze complex latent variables, and is effective in using small sample sizes without having to meet the assumption of data normality [Ghozali, 2021].

III. RESULT AND DISCUSSION

3.1. Identify Supply Chain Digitalization and Sustainability Indicators

At the initial stage, an identification process was conducted to determine various indicators related to supply chain digitalization and sustainability that are relevant to the conditions of MSMEs in Padang. These indicators were collected and adapted from a range of pertinent scientific publications. Subsequently, indicators that were considered inconsistent with the actual operational characteristics and context of MSMEs in Padang were eliminated. This screening process was intended to ensure that only indicators relevant to the focus and practical conditions of the study were retained. In addition, indicators with similar meanings or conceptual definitions were merged and reorganized into more representative indicators. The indicators of supply chain digitalization consisted of 11 indicators, which were adapted from [Joshi dan Sharma, 2022], [Lee et al, 2024], [Widowati et al, 2023], and [Zekhnini et al, 2022]. Meanwhile, the sustainability indicators were adopted from [Syahfitri, 2024] and comprised 7 economic indicators, 9 environmental indicators, and 9 social indicators.

3.2. Conceptualization of Model Construction

This stage involves the development of the structural model and the measurement model. The structural model (inner model) in this study is designed to represent the causal relationships among latent variables that form the conceptual framework of the influence of supply chain digitalization on the sustainability of MSMEs in Padang. The direction of the arrows in the model illustrates the cause-and-effect relationships established based on the formulated research hypotheses.

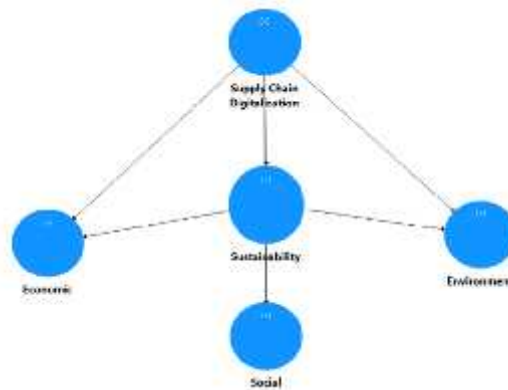


Figure 2. Inner Model

Subsequently, the measurement model (outer model) is developed to link latent variables with their corresponding measurement indicators. The measurement model (outer model) is designed to explain the relationship between manifest variables or indicators and the latent constructions they represent. These indicators function as measurement instruments that represent and describe latent variables that cannot be directly observed. [Ghozali, 2021].

3.3. Path Diagram Design

At this stage, the structural model (inner model) and the measurement model (outer model) are integrated to form a Hierarchical Component Model (HCM), as illustrated in Figure 4. The HCM approach is employed to represent the interrelated relationships between supply chain digitalization and sustainability constructs. Therefore, the model is structured hierarchically to clearly demonstrate the relationships between the main constructs and their corresponding sub-constructs.

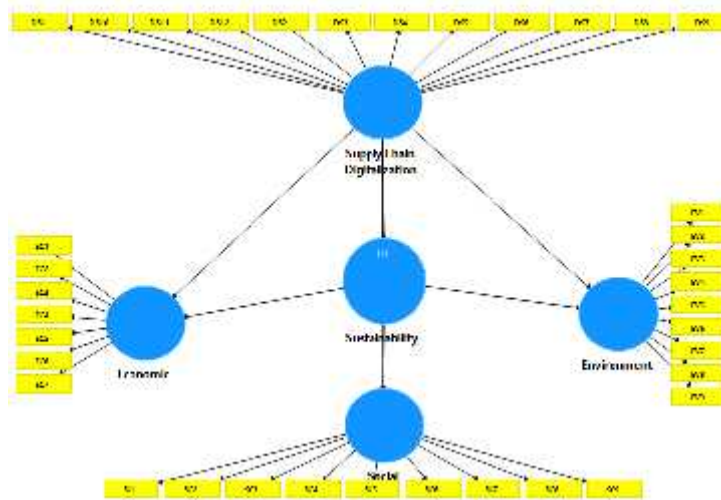


Figure 3. Path Diagram

3.4. Model Evaluation

The evaluation of the model was carried out by validity and reliability tests. According to [Ghozali, 2021] The measurement model (*outer model*) with indicators in the form of reflective is evaluated based on the *convergent validity* value and the *discriminant validity* value of the indicators that form the latent construct.

Convergent validity is related to the principle that the manifest variable (indicator) of a latent

variable (construct) should have a high correlation. The value of the convergent validity test using SmartPLS 3.0 software can be seen from the value of the loading factor (outer loading) on each indicator. According to [Ghozali, 2021] for the early stages of research and measurement scale development, loading factor values in the range of 0.50–0.60 are still considered acceptable. However, indicators with loading factor values below 0.50 indicate a weak contribution to the

construction and insufficient shared variance, which may reduce construct reliability and validity. Therefore, such indicators should be eliminated to improve the quality of the measurement model and ensure that each construct is well represented by its indicators.

Based on the outer loading results shown in Figure 2, six indicators have loading factor values below 0.50 and were consequently removed from the model, namely EC7 (There are efforts to improve product quality), EV4 (The use of materials used for product manufacturing is carried out optimally), SC4 (Attention to the health and safety aspects of employees), SC7 (Attention to the health and safety aspects of the customer), SC8 (Customer satisfaction level), and SC9 (The company's commitment to corruption prevention).

These indicators were eliminated because low outer loading values indicate that the indicators do not adequately reflect or share sufficient variance with their underlying constructs, implying a weak contribution to the explanation of the latent variables and a higher likelihood of introducing noise measurement rather than a meaningful signal. In PLS-SEM, indicators with low outer loadings are considered problematic as they may weaken convergent validity, reduce composite reliability, and impair the clarity and interpretability of the measurement model. Therefore, the elimination of such indicators is a common and recommended practice to improve

overall measurement quality and ensure that retained indicators meaningfully represent their respective constructs. Previous empirical studies and methodological guidelines confirm that removing indicators with insufficient loading values is an essential step in refining reflective measurement models, particularly when indicators fail to meet the minimum loading threshold and do not contribute significantly to construct reliability and validity. [Safitri dan Huda, 2023].

For example, indicators such as EC7 and EV4 require formalized quality improvement processes and documented performance tracking, which many Indonesian food MSMEs have yet to adopt due to limited digital infrastructure and low digital literacy. This often results in reliance on informal practices rather than standardized or digital management systems, reducing the empirical observability of these indicators. [Bachtiar et al, 2025]. Similarly, indicators related to health and safety (SC4, SC7) and customer satisfaction (SC8) lack formal monitoring mechanisms in many small enterprises because operational procedures and digital feedback systems are rarely implemented, making them difficult to quantify. Moreover, normative practices such as anti-corruption commitment (SC9) are not typically operationalized in routine MSME activities, further weakening their statistical relevance in reflective measurement models [Aripin et al, 2024], [Anatan dan Nur, 2023].

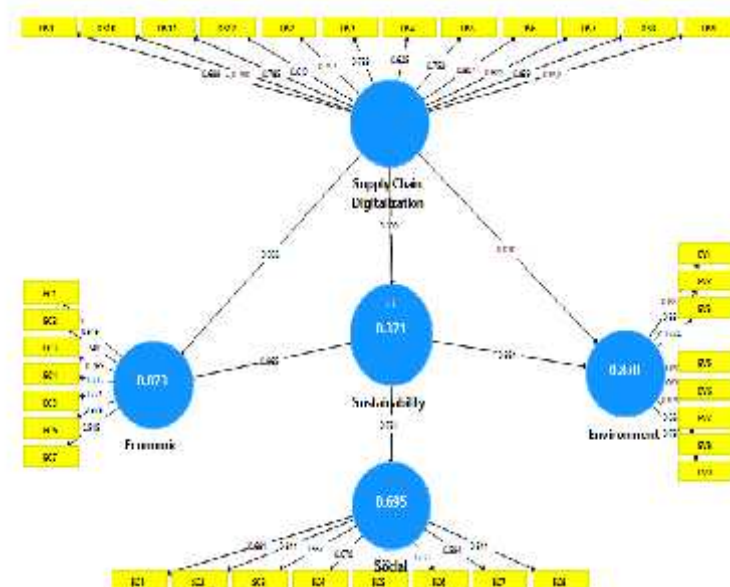


Figure 4. Outer Loading

The model has also met the discriminant validity test because the crossloading value on the measurement indicator is greater than that of the other measurement indicators.

Furthermore, a reliability test was carried out, which aimed to prove the consistency, accuracy, and reliability of the research instrument in measuring constructs. Through SmartPLS 3.0 software, the reliability test is seen from the composite reliability (CR) value. According to [6] The composite reliability for confirmatory research must be greater than 0.7 (>0.70). Based on Table 1, the composite reliability value for all latent variables is greater than 0.7. Thus, it can be

concluded that the reliability of the measurement instrument has been met and is acceptable.

Table 1. Composite Reliability

Variabel	Composite Reliability
Economic	0.893
Environment	0.923
Social	0.861
Supply Chain Digitalization	0.943
Sustainability	0.946

3.5. Hypothesis testing

Hypothesis testing is conducted using the bootstrapping procedure in SmartPLS 3.0. Several studies recommend employing 5,000 bootstrap samples to obtain more accurate standard error estimates, with a significant level of 5%. A hypothesis is considered supported when the resulting p-value is below 0.05 (alpha) or when the calculated t-statistic exceeds the critical t-value of 1.96 [6]. The alpha level () indicates the acceptable threshold of error tolerance in the study. Based on the results of data processing as shown in Table 2, only one hypothesis was accepted, namely H1, while the other hypothesis was rejected.

3.6. Discussion of Results

Based on the bootstrapping results obtained from SmartPLS 3.0, this study demonstrates that supply chain digitalization exerts a significant

positive influence on overall sustainability, while its direct effects on the economic, social, and environmental dimensions are not statistically significant when examined individually. This pattern of results suggests that the contribution of digitalization to sustainability is systemic rather than isolated, indicating that digital technologies function as an enabling infrastructure that enhances sustainability performance through integrated and cumulative mechanisms.

The significant relationship between supply chain digitalization and overall sustainability implies that digital transformation facilitates coordination, transparency, and information sharing across supply chain actors, which collectively strengthen sustainability outcomes. Rather than directly improving each sustainability dimension, digitalization appears to operate as a mediating or integrative.

Table 2. Hypothesis Testing

Hypothesis	Construct	T Statistics	P Values	Decision	Description
H1	Supply Chain Digitalization -> Sustainability	10.803	0.000	Accept H1	Significant Impact
H1a	Supply Chain Digitalization -> Economic	0.752	0.452	Reject H1a	Not Significant Impact
H1b	Supply Chain Digitalization -> Social	0.928	0.354	Reject H1b	Not Significant Impact
H1c	Supply Chain Digitalization -> Environment	0.379	0.705	Reject H1c	Not Significant Impact

mechanism that aligns economic efficiency, environmental responsibility, and social considerations into a unified sustainability framework. This finding supports prior studies emphasizing that digital supply chains promote sustainable development when technological adoption is accompanied by organizational readiness and strategic alignment. [Li et al, 2023].

Conversely, the non-significant direct effects on the economic, social, and environmental dimensions indicate that digitalization alone may be insufficient to generate immediate or measurable improvements in these areas. From an economic perspective, digital technologies may initially increase investment and operational complexity, thereby delaying observable financial benefits. Similarly, improvements in environmental and social performance often require complementary practices, such as regulatory compliance, green innovation, workforce engagement, and ethical governance, which extend beyond mere technological adoption. This explanation is consistent with previous research suggesting that digital transformation does not automatically translate into sustainability performance without adequate supply chain integration and managerial capability. [Damar dan Nursyamsyah, 2023].

Moreover, the findings highlight the importance of analytical and interpretive capabilities, such as big data analytics, in transforming digital data into actionable insights that support sustainability decision-making. Without such capabilities, digital tools may function primarily as operational instruments rather than strategic drivers of sustainability. [Lemoun et al, 2021]. This reinforces the argument that the impact of digitalization on sustainability is highly contingent on

organizational strategy, data utilization, and the maturity of digital implementation.

Overall, this study contributes to the sustainability and supply chain literature by demonstrating that supply chain digitalization is more effective in enhancing sustainability at a holistic level rather than influencing each sustainability dimension independently. These results imply that managers and policymakers should view digitalization not as a standalone solution, but as part of an integrated sustainability strategy that combines technological, organizational, and analytical components to achieve meaningful and long-term sustainable outcomes. [Junge dan Straube, 2020].

V. CONCLUSION

This study examined the impact of supply chain digitalization on the sustainability of food MSMEs in Padang using a PLS-SEM approach with SmartPLS 3.0. The empirical results demonstrate that supply chain digitalization has a significant positive effect on sustainability when sustainability is conceptualized as an integrated construct comprising economic, social, and environmental dimensions. This finding confirms that the adoption of digital technologies across supply chain activities plays an important role in strengthening the overall sustainability of food MSMEs through systemic and cumulative mechanisms. However, the results also indicate that the direct effects of supply chain digitalization on the economic, social, and environmental dimensions individually are not statistically significant. This suggests that the benefits of digitalization are not immediately or independently reflected in specific sustainability dimensions. Instead, digitalization functions as an enabling infrastructure that supports sustainability

outcomes holistically, rather than producing isolated improvements in economic performance, social responsibility, or environmental management.

In the context of food MSMEs in Padang, this condition can be explained by the relatively low level of digital maturity, limited organizational readiness, and the predominance of informal operational practices. Digital technologies are often adopted in a fragmented manner and have not yet been fully integrated into managerial decision-making, sustainability reporting, or performance evaluation systems. Consequently, digitalization alone is insufficient to generate measurable impacts on individual sustainability dimensions without complementary factors such as supply chain integration, managerial capability, data analytics utilization, and supportive institutional frameworks.

The findings of this study contribute theoretically by reinforcing the importance of adopting a holistic sustainability perspective when analyzing the impact of supply chain digitalization, particularly in MSME contexts. Practically, the results imply that policymakers and MSME practitioners should promote integrated digital transformation strategies rather than isolated technological adoption. Efforts to enhance MSME sustainability should therefore combine digital tools with organizational development, capacity building, and coordinated supply chain collaboration to achieve meaningful and long-term sustainable outcomes.

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