GIJEA
Greenation International Journal of Economics and Accounting
+62 81210467572 https://research.e-greenation.org/GIJEA greenation.info@gmail.com
GREENATION RESEARCH

DOI: https://doi.org/10.38035/gijea.v4i4.1328
https://creativecommons.org/licenses/by/4.0/
Received: 15 August 2026 | **Revised:** 05 September 2026 | **Accepted:** 17 October 2026

Agribusiness Economic Sustainability in Indonesia: A System Thinking and System Dynamics Model of Productivity, Market Access, Value Chain Integration, and Farmers' Welfare

Jan Hotman[1]
[1]Universitas Terbuka, Indonesia, hotman@ecampus.ut.ac.id

Corresponding Author: hotman@ecampus.ut.ac.id[1]

Abstract: Agribusiness plays a strategic role in strengthening agricultural economic sustainability through the interaction of productivity, market access, value-chain efficiency, and farmers' welfare. However, agricultural economic performance emerges from complex feedback relationships among production, market conditions, income, investment, and agribusiness capabilities. This study develops a conceptual System Thinking and System Dynamics framework for analysing agribusiness economic sustainability in Indonesia. Using a structured model-development approach based on the literature, the study identifies key causal relationships and formulates reinforcing and balancing feedback mechanisms linking agricultural productivity, market access, value-chain integration, production costs, farmers' income, reinvestment, digitalization, and agribusiness capability. These relationships are organized into a Causal Loop Diagram (CLD) and a conceptual stock-and-flow structure that specify the principal accumulations, rates, auxiliary variables, and policy intervention points. Three policy scenarios—Business-as-Usual, Value-Chain Integration, and Integrated Agribusiness Transformation—are formulated as analytical scenarios for subsequent quantitative simulation. Because the present study is conceptual and does not yet report calibrated numerical simulation, its contribution lies in providing a dynamic policy architecture and a transparent pathway for future empirical calibration, validation, sensitivity analysis, and scenario testing. The framework highlights potential leverage points through which coordinated interventions may strengthen farmers' economic capacity and long-term agribusiness sustainability.

Keyword: Agribusiness, Agricultural Economics, Farmers' Welfare, System Thinking, System Dynamics, Value Chain, Economic Sustainability.

INTRODUCTION

Agriculture remains a strategic sector in supporting economic development, rural livelihoods, food security, and employment, particularly in developing countries. However, the contribution of agriculture to economic welfare cannot be assessed only from the perspective of agricultural production. The development of modern agriculture increasingly

depends on the integration of production, processing, distribution, marketing, technology, finance, and institutional support within an agribusiness system. Diao et al. (2024) explain that agricultural transformation progressively extends beyond primary production toward processing, packaging, transportation, trading, and other non-farm activities that connect rural producers with broader markets. Therefore, agribusiness development should be understood as an interconnected economic system rather than as an isolated agricultural activity.

The sustainability of agribusiness is closely associated with the ability of farmers and other value-chain actors to generate sufficient and sustainable economic value. FAO (2024) emphasizes that agrifood systems generate substantial economic, social, and environmental benefits, while simultaneously producing hidden costs that require coordinated policy interventions. The transformation of agrifood systems therefore requires the involvement of producers, agribusiness enterprises, consumers, governments, and other stakeholders. Similarly, FAO (2025) argues that sustainable agribusiness and agrifood value chains require stronger market access, productive resources, information, technology, value addition, and coordination among value-chain actors.

One of the fundamental challenges in agricultural economic development is the weak transmission of economic value from downstream markets to primary producers. Smallholder farmers frequently face limited market access, production constraints, information asymmetry, inadequate infrastructure, limited financial resources, and weak coordination with other actors in the value chain. These conditions can reduce bargaining power and limit farmers' ability to capture value from agricultural products. Trienekens (2011) emphasizes that competitiveness in agricultural value chains is influenced not only by production capability but also by coordination, institutional support, infrastructure, resources, and market linkages. Thus, improving farmers' welfare requires interventions that address the structure of the entire value chain rather than focusing exclusively on farm-level productivity.

Market dynamics further complicate the sustainability of agricultural economic systems. Agricultural prices are influenced by production volumes, seasonal patterns, demand, distribution, market governance, and environmental conditions. Price volatility can generate uncertainty for farmers and other value-chain actors, affecting production decisions, investment, and income. In the Indonesian agricultural context, Muflikh et al. (2021) demonstrate that agricultural price volatility is a complex systemic problem in which changes in one part of the value chain can generate unintended consequences elsewhere. Their systems-thinking analysis of the Indonesian chilli value chain shows that price fluctuations are associated with interconnected feedback structures involving production, marketing, and governance.

This complexity indicates the limitation of conventional analytical approaches that primarily examine linear relationships between independent and dependent variables. Agribusiness systems contain multiple feedback loops, nonlinear relationships, delays, accumulation processes, and interactions among economic, social, technological, and institutional factors. Sterman (2000) argues that complex socioeconomic problems require an understanding of the underlying system structure that generates observed patterns of behavior. Similarly, Maani and Cavana (2007) emphasize that systems thinking provides a framework for identifying feedback structures and understanding how interventions may produce consequences over time.

System Dynamics provides an appropriate methodological framework for addressing these characteristics. Unlike static value-chain analysis, System Dynamics allows researchers to represent feedback relationships, stocks, flows, time delays, and nonlinear interactions and subsequently simulate system behavior under alternative scenarios. Rich et al. (2011) demonstrate that System Dynamics can be integrated into agricultural value-chain analysis to examine dynamic interactions and evaluate policy interventions. A systematic review by

Muflikh et al. (2021) further confirms that System Dynamics offers advantages in capturing feedback, dynamic behavior, time delays, multiple causal factors, and the effects of policy interventions over time.

Recent empirical evidence also demonstrates the relevance of this approach in the Indonesian agricultural sector. Muflikh et al. (2024) developed a System Dynamics model integrated with value-chain analysis to investigate price volatility in the Indonesian chilli value chain. Their study demonstrates that System Dynamics can be used to identify underlying causes of price volatility, evaluate alternative policy scenarios, and examine their distributional implications for smallholder farmers.

Although these studies provide important contributions, an opportunity remains to develop a more comprehensive dynamic model that integrates agricultural productivity, market access, value-chain integration, production costs, farmers' income, reinvestment, and agribusiness capability within a single economic sustainability framework. Existing studies tend to focus on specific commodities or specific problems, such as price volatility, certification, or circular-economy implementation. A broader agribusiness economic model is needed to explain how interventions in one component of the system may generate reinforcing or balancing effects across other components.

This study therefore adopts a Systems Thinking and System Dynamics perspective to develop a dynamic model of agribusiness economic sustainability. The proposed model conceptualizes farmers, agribusiness enterprises, markets, value-chain institutions, and policy interventions as interconnected components of an agricultural economic system. The model incorporates causal relationships among productivity, production, market access, value-chain efficiency, production costs, farmers' income, reinvestment, and agribusiness capability. The resulting causal structure is subsequently translated into a stock-flow model to simulate the behavior of the system over time.

The main contribution of this study is the development of an integrated dynamic framework that moves beyond a simple linear explanation of agricultural economic performance toward a feedback-based explanation of agribusiness sustainability. The conceptual model is designed to identify candidate leverage points and formulate alternative intervention scenarios for subsequent simulation, including business-as-usual conditions, agribusiness value-chain integration, and an integrated strategy involving digitalization and farmer empowerment. By examining the long-term consequences of these scenarios, the study seeks to provide evidence for policymakers, agribusiness managers, farmer organizations, and other stakeholders in designing more effective strategies for improving farmers' economic welfare and strengthening the sustainability of the agricultural economy.

Accordingly, this study addresses the following research question: How can the interactions among agricultural productivity, market access, value-chain integration, farmers' income, reinvestment, and agribusiness capability be represented as a dynamic feedback structure for analysing agribusiness economic sustainability? More specifically, the study seeks to (1) identify the dominant reinforcing and balancing feedback structures, (2) formulate the corresponding stock-and-flow architecture, and (3) develop alternative policy scenarios that can be tested after empirical calibration and validation.

METHOD

Research Design

This study employs a conceptual model-development design combining Systems Thinking and System Dynamics. The objective is not to estimate causal effects from a single cross-sectional dataset, but to formulate an explicit dynamic structure that can subsequently be calibrated and simulated. The modelling process follows five stages: problem articulation and boundary definition; identification of key variables and causal relationships; construction

of reinforcing and balancing feedback loops; translation of the causal structure into a stock-and-flow architecture; and formulation of policy scenarios and a validation protocol.

Model Boundary and Variable Selection

The model boundary covers the economic dimension of agribusiness sustainability at the interaction of farm production, market access, value-chain coordination, investment, capability development, and digitalization. Variables were selected from the literature reviewed in the Introduction and organized according to their functional role in the system. The principal endogenous variables are agribusiness capability, productive capacity, farmers' economic capital, productivity, production, market access, value-chain efficiency, production costs, farmers' income, reinvestment, and economic sustainability. External conditions such as macroeconomic shocks, extreme weather, and commodity-specific demand shocks are treated as exogenous contextual factors in the present conceptual model.

Causal and Stock-Flow Model Formulation

Causal relationships were formulated using polarity and feedback logic. A positive link indicates that variables tend to move in the same direction, whereas a negative link indicates an inverse relationship, ceteris paribus. Reinforcing loops represent cumulative growth or decline mechanisms, while balancing loops represent constraints that counteract change. The resulting Causal Loop Diagram (Figure 1) is translated into a conceptual stock-and-flow structure (Figure 2). The three principal stocks are agribusiness capability, productive capacity, and farmers' economic capital. Their levels change through capability development, capacity formation and depreciation, income accumulation, and productive reinvestment.

Scenario Formulation and Simulation Readiness

Three scenarios are formulated for future quantitative experimentation: (1) Business-as-Usual (BAU), representing continuation of existing structural conditions; (2) Value-Chain Integration, representing improvements in coordination, market connectivity, and efficiency; and (3) Integrated Agribusiness Transformation, combining value-chain integration, digitalization, farmer empowerment, and productive reinvestment. No numerical simulation outputs are claimed in this manuscript because parameter values and empirical calibration are not yet available. Accordingly, the scenarios should be interpreted as structured policy hypotheses rather than empirical findings.

Validation and Sensitivity Analysis Protocol

Before quantitative policy conclusions are drawn, the model should undergo: (1) structural validation through expert review of causal relationships and boundary assumptions; (2) dimensional-consistency testing of all equations; (3) extreme-condition and behavior-reproduction tests after calibration; and (4) sensitivity analysis for influential parameters, particularly market-access responsiveness, value-chain efficiency, productivity growth, reinvestment ratio, production costs, digitalization, and farmer capability. This protocol is specified to make the transition from the present conceptual model to a validated simulation model transparent and reproducible.

RESULT AND DISCUSSION

Conceptual Systems Thinking Results

The Systems Thinking analysis identifies agribusiness economic sustainability as an interconnected conceptual system consisting of production, market, value-chain, financial, technological, and institutional components. The relationships specify hypothesised

mechanisms to be operationalised in a subsequent quantitative System Dynamics model; they should therefore not be interpreted as empirically validated simulation results.

Table 1. Systems Thinking Structure and Feedback Mechanisms

No	System Thinking Component	Causal Relationship	Feedback Type	Expected System Behavior
1	Agribusiness capability → Productivity → Income → Reinvestment → Agribusiness capability	Higher capability increases productivity and income, which stimulates reinvestment and further capability development	Reinforcing (R1)	Virtuous cycle of agribusiness growth
2	Market access → Sales → Farmers' income → Reinvestment → Productivity	Improved market access increases sales opportunities and income, encouraging productive investment	Reinforcing pathway (R2, via investment and capability)	Increasing productivity and income
3	Value-chain integration → Efficiency → Production cost → Farmers' income	Better coordination reduces inefficiency and costs, improving economic returns; the pathway becomes reinforcing when additional income supports reinvestment and capability development.	Enabling pathway; becomes reinforcing when closed through reinvestment/capability	Improved value capture
4	Productivity → Production → Market supply → Agricultural price → Farmers' income	Increasing production may increase market supply and create downward pressure on prices	Balancing (B1)	Growth constrained by market absorption
5	Production cost → Farmers' income → Reinvestment → Productivity	Higher production costs reduce income and investment capacity	Balancing constraint (B2)	Restriction on productivity growth
6	Digitalization → Market information → Market access → Farmers' income → Digital investment	Better information improves market participation and creates incentives for further digital adoption	Potential reinforcing (R3)	Accelerating market integration
7	Farmer empowerment → Capability → Technology adoption → Productivity → Income	Improved human and organizational capability increases technology adoption and productivity	Potential reinforcing (R4)	Long-term capability accumulation

The System Thinking analysis indicates that farmers' income is not merely an outcome variable but also an important feedback mechanism. Higher income increases the capacity for reinvestment, while reinvestment contributes to productivity and agribusiness capability. Conversely, high production costs and limited market absorption may create balancing mechanisms that constrain the growth of the system.

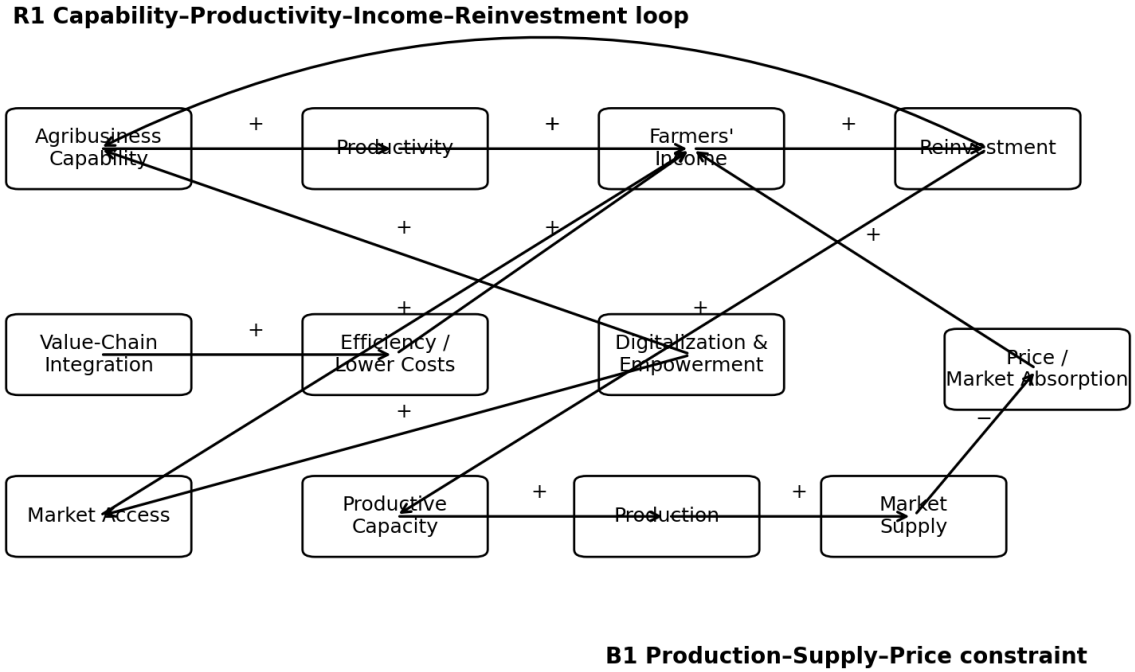


Figure 1. Conceptual Causal Loop Diagram (CLD) of Agribusiness Economic Sustainability

Conceptual System Dynamics Architecture

The causal relationships identified through Systems Thinking are translated into a conceptual System Dynamics architecture consisting of stocks, flows, auxiliary variables, and feedback structures. At the current stage, the architecture defines model logic and equation domains but does not constitute a calibrated numerical simulation.

Table 2. Conceptual System Dynamics Architecture

No	SD Element	Main Variable	Function in the Model	Expected Dynamic Effect
1	Stock	Agribusiness Capability	Accumulates knowledge, managerial capability, technology, and organizational capacity	Long-term increase in system capacity
2	Stock	Productive Capacity	Represents accumulated production potential	Determines future production capability
3	Stock	Farmers' Economic Capital	Represents accumulated financial resources available for reinvestment	Determines investment capacity
4	Flow	Capability Development	Increases agribusiness capability through training, technology, and institutional support	Strengthens productive capacity
5	Flow	Production	Converts productive capacity into agricultural output	Increases market supply
6	Flow	Reinvestment	Allocates part of farmers' income to productive activities	Increases future productivity
7	Auxiliary	Market Access	Represents farmers' ability to reach and participate in markets	Improves sales opportunities
8	Auxiliary	Value-Chain Efficiency	Represents coordination and efficiency among value-chain actors	Reduces transaction and production inefficiencies
9	Auxiliary	Production Cost	Represents costs associated with agricultural production and distribution	Reduces net farmers' income
10	Auxiliary	Farmers' Income	Net economic return obtained from agricultural activities	Drives reinvestment
11	Auxiliary	Digitalization	Represents adoption of digital technology for information, marketing, and transactions	Improves market access and coordination

No	SD Element	Main Variable	Function in the Model	Expected Dynamic Effect
12	Output	Agricultural Productivity	Measures output generated per unit of productive resources	Key performance indicator
13	Output	Farmers' Welfare	Represents the economic outcome of the agribusiness system	Main socioeconomic outcome
14	Output	Economic Sustainability	Represents the long-term capacity of the system to maintain economic performance	Main model outcome

Conceptual Stock-and-Flow Architecture (parameterization required for simulation)

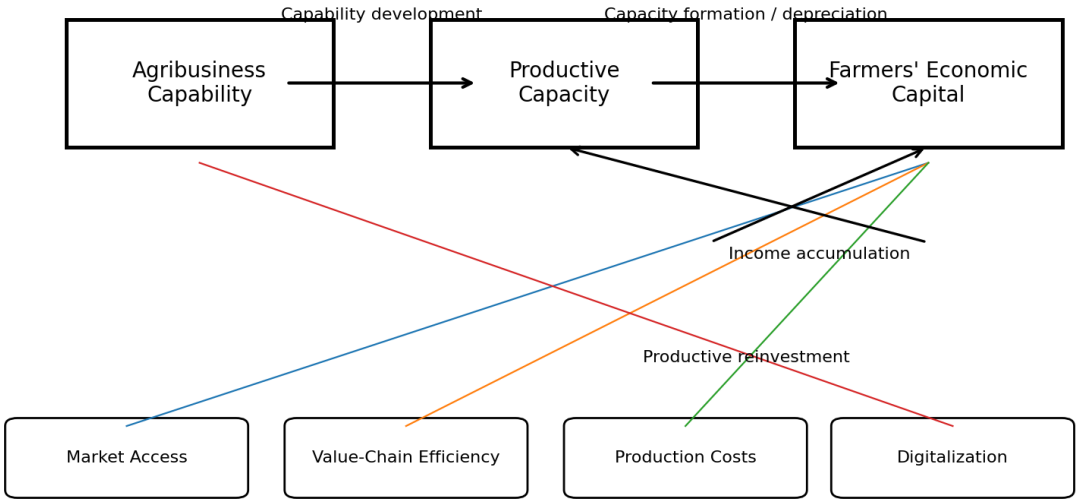


Figure 2. Conceptual Stock-and-Flow Structure of the Proposed Model

Policy Scenario Structure

The model specifies three alternative policy scenarios for future quantitative simulation. Their descriptions represent analytical hypotheses about intervention mechanisms rather than observed or simulated outcomes.

Table 3. Policy Scenario Structure for Future Simulation

Scenario	Main Intervention	Expected Effect on Productivity	Expected Effect on Farmers' Income	Expected Effect on Economic Sustainability
Scenario 1: Business as Usual	Existing conditions maintained	Hypothesized low-to-moderate growth	Hypothesized limited growth	Hypothesized relatively weak sustainability
Scenario 2: Value Chain Integration	Improved coordination, market access, and value-chain efficiency	Hypothesized higher growth	Hypothesized higher income	Hypothesized improved sustainability
Scenario 3: Integrated Agribusiness Transformation	Value-chain integration + digitalization + farmer empowerment + reinvestment	Potentially highest growth, subject to simulation	Potentially highest income, subject to simulation	Potentially strongest sustainability, subject to simulation

Summary of Conceptual Model Outputs

The conceptual Systems Thinking analysis identifies reinvestment, market access, value-chain integration, and agribusiness capability as candidate leverage points within the agricultural economic system. The proposed System Dynamics architecture suggests how interventions in these variables could propagate through reinforcing and balancing

mechanisms over time. At this stage, however, the relative magnitude, timing, and robustness of these effects cannot be inferred without parameterization and numerical simulation. The model should therefore be read as a theory-informed dynamic architecture that guides subsequent calibration and policy experimentation.

Future simulation should report time-series indicators for productivity, farmers' income, market access, agribusiness capability, and economic sustainability, together with uncertainty or sensitivity ranges. These outputs should only be interpreted after the model has passed structural, dimensional-consistency, and behavioral validation tests.

Discussion

The conceptual model suggests that agribusiness economic sustainability should be understood as a dynamic system rather than as the result of a single economic factor. The Systems Thinking analysis specifies interconnected relationships among agricultural productivity, market access, value-chain integration, production costs, farmers' income, reinvestment, digitalization, and agribusiness capability. The proposed System Dynamics architecture translates these relationships into feedback mechanisms that provide hypotheses about how agricultural economic performance may evolve over time. This interpretation is consistent with Sterman (2000), who argues that complex socioeconomic outcomes are generated by the interaction of feedback structures rather than isolated causal relationships.

1. Agribusiness Capability as a Reinforcing Mechanism

One of the central mechanisms proposed by the conceptual model is the reinforcing relationship between agribusiness capability, productivity, farmers' income, and reinvestment. Improvements in agribusiness capability can increase farmers' ability to manage production resources, adopt technology, access markets, and coordinate with other value-chain actors. Higher productivity may subsequently generate greater economic returns, providing additional resources for reinvestment.

This relationship creates a reinforcing loop in which economic improvement can generate further economic improvement. In System Dynamics terminology, this represents a positive feedback loop (R1). The implication is important because policies aimed only at increasing short-term agricultural production may produce limited effects if they do not simultaneously strengthen the capabilities required to maintain and reproduce productive capacity.

The proposed mechanism is consistent with the broader argument that agricultural transformation requires improvements not only in physical production but also in knowledge, managerial capability, technology, institutions, and market connectivity. FAO (2025) emphasizes that sustainable agribusiness requires access to productive resources, information, technology, markets, and value addition. Thus, capability development should be treated as an endogenous component of agricultural economic sustainability rather than merely as an external supporting factor.

2. Market Access and Farmers' Income

The model also identifies market access as a critical leverage point. Increased market access provides farmers with more opportunities to sell agricultural products, potentially improving sales volume, price realization, and income. Higher income can subsequently increase farmers' capacity to reinvest in production, creating another reinforcing mechanism.

This conceptual relationship highlights an important distinction between production-oriented agriculture and market-oriented agribusiness. Increasing agricultural output does not automatically increase farmers' welfare when farmers face weak market access, asymmetric information, high transaction costs, or limited bargaining power. Trienekens (2011) argues that value-chain competitiveness depends on coordination among actors and the ability to

connect producers with markets. Therefore, policies that improve production without improving market access may fail to generate proportional improvements in farmers' income.

From a System Thinking perspective, market access is therefore not simply an output of the agricultural system. It also functions as an input that influences farmers' future production and investment decisions. This reciprocal relationship explains why interventions that strengthen market connectivity may produce cumulative effects over time.

3. Value-Chain Integration as a Policy Leverage Point

The Systems Thinking analysis further suggests that value-chain integration can reduce inefficiencies and improve the distribution of economic value among agricultural actors. Fragmentation between farmers, collectors, processors, distributors, retailers, and consumers may increase transaction costs and weaken farmers' bargaining positions.

Value-chain integration changes this structure by improving coordination, information exchange, logistics, processing, marketing, and value addition. As efficiency improves, production and transaction costs may decline while the economic value captured by farmers and other actors can increase.

The importance of this mechanism is also reflected in previous System Dynamics research on agricultural value chains. Muflikh et al. (2021) demonstrate that agricultural value-chain problems are characterized by complex feedback relationships and that policy interventions can generate different effects depending on the structure of the system. Their findings support the argument that agricultural policies should be evaluated according to their system-wide consequences rather than their direct effects alone.

The present model extends this perspective by linking value-chain integration not only to agricultural prices but also to farmers' income, reinvestment, productivity, and long-term agribusiness capability. Thus, value-chain integration may function as a strategic leverage point connecting market performance with productive capacity.

4. The Role of Reinvestment in Creating Long-Term Economic Sustainability

Another important mechanism specified in the conceptual model is the role of reinvestment. Farmers' income influences their ability to invest in production capacity, technology, inputs, infrastructure, and other productive resources. Reinvestment subsequently affects productivity and future income.

This creates a time-dependent relationship that is difficult to capture through static models. The impact of current income on future productivity may not occur immediately because investments require time before generating productive returns. System Dynamics is particularly useful for representing this time delay.

Consequently, a policy that produces an immediate increase in farmers' income may generate a much larger long-term effect if part of the additional income is converted into productive investment. Conversely, if additional income is not translated into productive capacity, the long-term effect may be considerably weaker.

This conceptual mechanism suggests that agricultural economic policy should distinguish between income enhancement and productive income enhancement. The latter may be more likely to generate a reinforcing cycle because current economic gains can be transformed into future productive capacity.

5. Balancing Mechanisms and the Risk of Overproduction

Although the model contains several reinforcing loops, the agricultural system also contains balancing mechanisms. One important mechanism is the relationship between production volume and market price. Increasing production may initially increase farmers' income; however, when market supply increases faster than market demand, prices may decline and reduce the expected economic benefit.

This represents a balancing loop (B1) and demonstrates why agricultural development cannot be based solely on increasing production. Productivity growth must be accompanied

by market development, processing capacity, product diversification, storage, logistics, and downstream value addition.

The existence of balancing mechanisms is particularly important for policy analysis. A policy designed to increase production may generate positive outcomes under one set of market conditions but produce unintended consequences under another. This is precisely the type of counterintuitive behavior that System Dynamics is designed to investigate (Sterman, 2000).

6. Digitalization and Farmer Empowerment

The integrated transformation scenario introduces digitalization and farmer empowerment as additional drivers of agribusiness development. Digitalization can improve access to market information, facilitate transactions, connect farmers with buyers, and improve coordination throughout the value chain.

However, digitalization should not be interpreted as an independent technological solution. Its economic impact depends on farmers' capabilities, access to infrastructure, institutional support, and willingness to adopt new practices. Consequently, digitalization and farmer empowerment are represented as interconnected components in the model.

This perspective is important because technology adoption may create stronger effects when combined with human and organizational capability. A digitally connected farmer with limited managerial or market capability may not capture the full economic benefits of digital technology. The model therefore treats digitalization as a reinforcing mechanism rather than as a standalone intervention.

7. Comparison of Policy Scenarios

The scenario hypotheses suggest that the Business-as-Usual condition may generate relatively limited improvement because the existing structural constraints remain unchanged. This proposition requires numerical testing after calibration.

The Value-Chain Integration scenario is hypothesised to improve outcomes by intervening in the relationships between farmers and markets. Improvements in coordination and market access may increase income and create opportunities for further investment, subject to parameter values and behavioral validation.

The Integrated Agribusiness Transformation scenario is formulated as a hypothesis of stronger long-term performance because it combines several reinforcing interventions. Whether these interventions generate cumulative gains, and under what conditions, remains a question for calibrated simulation.

A testable implication of the framework is that integrated policies may outperform isolated interventions when they strengthen complementary feedback structures. This proposition should be assessed through comparative scenario simulation rather than assumed as an empirical result.

8. Theoretical and Practical Implications

Theoretically, this study contributes to agricultural economics and agribusiness research by introducing a dynamic perspective in which farmers' welfare is generated through interactions among production, markets, capabilities, investment, and value-chain structures. Rather than treating farmers' income as a simple dependent variable, the model positions income as both an outcome and a feedback mechanism that influences subsequent productive investment.

Methodologically, the study demonstrates the value of integrating System Thinking and System Dynamics. System Thinking identifies the structure of the problem and its feedback relationships, while System Dynamics enables these relationships to be quantified and simulated over time. The integration of both approaches provides a stronger basis for understanding complex agricultural economic systems.

Practically, the model suggests that policymakers should prioritize interventions with high systemic leverage. These include strengthening farmer organizations, improving market connectivity, developing value-added processing, reducing transaction costs, expanding digital market access, increasing productive investment, and improving agribusiness capabilities.

9. Novelty of the Study

The principal novelty of this study lies in the formulation of an integrated Agribusiness Economic Sustainability System Dynamics architecture that connects productivity, market access, value-chain integration, production costs, farmers' income, reinvestment, digitalization, and agribusiness capability within a single feedback-based framework.

Previous studies have generally examined individual agricultural problems, including price volatility, value-chain efficiency, circular economy, or specific commodity systems. The proposed model goes further by explaining how these factors interact dynamically to generate long-term agricultural economic outcomes.

The model also identifies farmers' income as a central feedback variable. Income is simultaneously an economic outcome and a source of future reinvestment. This creates a reinforcing mechanism that provides a theoretical explanation of how agricultural economic development can either accelerate through a virtuous cycle or stagnate when market access, productivity, and investment remain constrained.

Therefore, the contribution of this study is not merely the application of Systems Thinking and System Dynamics to agriculture, but the formulation of a policy-oriented dynamic architecture that enables decision makers and future researchers to identify candidate leverage points and compare alternative agribusiness development strategies after empirical calibration and validation.

10. Implications for Policy Simulation

The conceptual framework provides a basis for the next stage of quantitative simulation. The most important variables for sensitivity testing are expected to include market access, value-chain efficiency, productivity growth, reinvestment ratio, production costs, digitalization, and farmer capability.

The simulation should subsequently determine whether the expected reinforcing mechanisms actually generate sustained improvement and whether balancing mechanisms limit the effectiveness of specific interventions. The results will allow policymakers to distinguish between interventions that produce short-term improvements and those capable of generating sustainable long-term effects.

In this respect, the value of the proposed System Dynamics model lies not in predicting a single future outcome, but in testing alternative futures under different assumptions and policy interventions. This provides a more appropriate basis for agricultural economic policy in a complex and changing agribusiness environment.

CONCLUSIONS AND RECOMMENDATIONS

This study develops a conceptual Systems Thinking and System Dynamics framework for analysing agribusiness economic sustainability in Indonesia. The framework specifies interactions among agricultural productivity, market access, value-chain integration, production costs, farmers' income, reinvestment, digitalization, and agribusiness capability as interconnected reinforcing and balancing mechanisms. The analysis therefore provides a structural explanation of why agricultural economic performance cannot be adequately represented through isolated linear relationships.

The proposed model positions farmers' income as both an economic outcome and a potential feedback mechanism because income can support reinvestment and subsequent capability and productive-capacity development. It also incorporates balancing constraints

associated with production costs and market absorption, highlighting the possibility that productivity growth may not translate automatically into sustainable welfare gains.

Three policy scenarios—Business-as-Usual, Value-Chain Integration, and Integrated Agribusiness Transformation—are formulated as hypotheses for future simulation. The framework suggests that coordinated interventions may activate complementary feedback mechanisms, but it does not claim numerical superiority of any scenario because the model has not yet been empirically calibrated or behaviorally validated.

The principal contribution of the study is thus the formulation of an integrated dynamic policy architecture and an explicit validation pathway. Future research should calibrate the stock-flow equations using Indonesian agricultural and agribusiness data, conduct structural and dimensional-consistency tests, reproduce relevant historical behavior where possible, and perform sensitivity and scenario analyses. These steps are necessary before the model can serve as a validated decision-support instrument for estimating the magnitude, timing, and robustness of policy effects on farmers' welfare and long-term economic sustainability.

REFERENCES

Badan Pusat Statistik. (2025). *Indikator ekonomi pertanian Indonesia*. Badan Pusat Statistik, Jakarta.

Badan Pusat Statistik. (2025). *Statistik Indonesia 2025*. Badan Pusat Statistik, Jakarta.

FAO. (2024). *The state of food and agriculture 2024: Value-driven transformation of agrifood systems*. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2025). *Sustainable agribusiness and agrifood value chain development*. Food and Agriculture Organization of the United Nations. https://www.fao.org/agrifood-economics/areas-of-work/smart/sustainable-agribusiness-agrifood-value-chain/en/

Forrester, J. W. (1961). *Industrial dynamics*. MIT Press.

Kementerian Pertanian Republik Indonesia. (2025). *Statistik pertanian 2025*. Kementerian Pertanian Republik Indonesia, Jakarta.

Maani, K. E., & Cavana, R. Y. (2007). *Systems thinking, system dynamics: Managing change and complexity* (2nd ed.). Pearson Education.

Muflikh, Y. N., Smith, C., & Aziz, A. A. (2021). A systematic review of the contribution of system dynamics to value chain analysis in agricultural development. *Agricultural Systems, 189*, 103044. https://doi.org/10.1016/j.agsy.2020.103044

Muflikh, Y. N., Smith, C., Brown, C., & Aziz, A. A. (2021). Analysing price volatility in agricultural value chains using systems thinking: A case study of the Indonesian chilli value chain. *Agricultural Systems, 192*, 103179. https://doi.org/10.1016/j.agsy.2021.103179

Muflikh, Y. N., Smith, C., Brown, C., Kusnadi, N., Kiloes, A. M., et al. (2024). Integrating system dynamics to value chain analysis to address price volatility in the Indonesian chilli value chain. *Food Policy*.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Irwin/McGraw-Hill.

Trienekens, J. H. (2011). Agricultural value chains in developing countries: A framework for analysis. *International Food and Agribusiness Management Review, 14*(2), 51–82.

World Bank. (2024). *Agriculture, food and rural development*. World Bank.