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Chapter: Financial Systems, Institutional Efficiency, and Policy Challenges of Economic and Institutional Structures

Symbiotic development relationship between regional agricultural industry clusters and agricultural logistics

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Annotation. Under the prevailing trend of coordinated industrial development, extending supply chains and strengthening industry linkages have emerged as critical pathways for upgrading modern agriculture. However, research into the dynamic symbiotic evolution mechanisms and optimization strategies of regional agricultural industry clusters and logistics systems remains insufficient, hindering the realization of high-quality collaborative growth. To advance the co-development of regional agricultural clusters and logistics, this study constructed a system dynamics model grounded in symbiosis theory. This model was applied to Jiangsu Province, China to investigate the feedback mechanisms and co-evolutionary trajectories of the cluster–logistics symbiotic system. First, the symbiotic units, environmental factors, and interaction patterns were synthesized to develop causal loop and stock–flow diagrams. Second, scenario simulations were conducted following parameter calibration and validity testing against historical data. Finally, the effects of policy support, labor return, and transportation improvements on system performance were assessed. Results indicate that Jiangsu's agricultural GDP will reach 1459.53 billion yuan by 2025. Elevating the policy support coefficient to 0.20 can increase cluster output value and logistics employment by approximately 3.92% and 3.50%, respectively. A 2% rise in labor supply yields a 17.44% increase in output value, and enhanced transportation accessibility boosts cluster output value and logistics capacity by 3.19% and 2.19%, respectively. Moreover, persistent rural labor outflow and logistics supply–demand imbalances are identified as principal constraints on collaborative development. These findings not only provide theoretical guidance for optimizing regional factor allocation and enhancing overall symbiotic system performance but also offer novel insights for advancing China's agricultural modernization through "place-based, differentiated strategies".

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JEL classification: L11, L42, M11.

Introduction

With the deepening of globalization and modernization, agriculture has evolved beyond a traditional sector focused only on grain production. It now fulfills multiple functions in ecological conservation, rural revitalization, and urban–rural integrated development. Nevertheless, China's agricultural modernization started relatively late. Its levels of mechanization, informatization, and organization still lag markedly behind those of developed countries, thereby constraining the scale, intensification, and digitization of agricultural operations (Huggins *et al.*, 2015; Painter, 2010). At the same time, international competition in agricultural markets has intensified, and consumer demands for food safety, environmental sustainability, and traceability continue to rise. These trends call for the rapid establishment of an efficient, collaborative industrial ecosystem. As the pivotal link between field and table, agricultural logistics determines the cost and quality of agrifood circulation. It encompasses transportation, storage, distribution, and information services. Currently, China's agricultural logistics landscape is characterized by advanced infrastructure in eastern regions, underdeveloped systems in central and western regions and rural areas, and a pronounced imbalance (Zhang *et al.*, 2024; Huseynov *et al.*, 2024). Its principal structure comprises self-operated networks, third-party providers, and e-commerce platforms; however, rural aggregation points and cold-chain systems remain incomplete (Li *et al.*, 2010). Prior studies have proposed macro level policies, including increased infrastructure investment, integration of e-commerce and logistics, and standardization improvements (Huang *et al.*, 2000; Franco *et al.*, 2024; Jamaesha *et al.*, 2024). They have also advanced micro level optimizations in node location, organizational models, and performance evaluation (Fu *et al.*, 2025; Jiang *et al.*, 2021; Yu *et al.*, 2014; Gao *et al.*, 2019). Nevertheless, these studies lack a holistic perspective that integrates logistics with industrial clusters.

In recent years, the coordination of agricultural industry clusters with logistics has emerged as a key driver of agricultural modernization. Industry clusters enhance regional competitiveness and value addition by spatially colocating homogeneous or complementary actors that share resources and collaborate (Chen *et al.*, 2024; Zhang *et al.*, 2024). Conversely, logistics elements, especially cold-chain, warehousing, and distribution efficiencies, directly affect the cost structure and quality preservation of agrifoods (Feng, 2020; Álvarez *et al.*, 2023). However, extant research tends to focus separately on either cluster formation or logistics optimization. It rarely conducts quantitative dynamic analyses or system simulations of their symbiotic interactions (Yu *et al.*, 2017; Wagner, 2008). Some literature has examined the lifecycle and stability of symbiotic systems (Shaout *et al.*, 2014; Narkunienė *et al.*, 2018), their environmental performance and innovation effects (Morosini, 2004), and energy-saving and emission-reduction pathways (Paracer *et al.*, 2000; Grönroos *et al.*, 2012). However, studies on the dynamic coupling between agricultural clusters and logistics within a symbiosis framework remain absent. In economic geography and industrial ecology, symbiosis theory has been adopted to describe "organic" interfirm relationships and by-product–raw-material cycles (Elagin *et al.*, 2021; Hinterberger *et al.*, 1997; Wang *et al.*, 2017; Niu *et al.*, 2023). It has evolved to emphasize integration, interaction, and coordination as core characteristics (Wang *et al.*, 2013; Wang *et al.*, 2021; Ullah *et al.*, 2022; Chien, 2022). This theory highlights how different production units can achieve systemic synergy through exchanges of resources, energy, and information, thereby offering a novel lens for exploring the coevolution of agricultural clusters and logistics (Wen *et al*., 2022).

Research on goodwill in the context of supply chains has become a significant area of study for scholars domestically and internationally. Nerlove and Arrow (2014) suggested that advertising investment can be regarded as an investment in a specific asset – namely, the accumulation of brand reputation. Dai *et al*. (2015) analyzed the optimal advertising decisions of monopolistic firms from the perspective of strategic consumers. Liu *et al*. (2015) assumed that advertising is a primary marketing tool and explored how companies with operating and marketing costs should make decisions regarding advertising investment. Lin *et al*. (2014) focused on how firms can strategically place online advertisements in the digital environment. However, most studies, including the aforementioned ones, have focused on individual firm decisions rather than on the cooperative dynamics within supply chains. By contrast, He *et al*. (2020) were the first to quantitatively analyze the determination of vertically cooperative advertising levels within a supply chain. Li *et al*. (2017) argued that advertising cooperation between enterprises not only facilitated dual-channel supply chain coordination but also enabled online and offline channels to achieve a win-win situation. Pnevmatikos *et al*. (2018) examined the influence of price and brand reputation on consumer demand and found that retailers' advertising investment in brand reputation not only enhances supply chain performance but also increases consumer surplus. Yu *et al*. (2018) applied differential game theory (DGT) to study the optimal strategy and profits in a green food supply chain, incorporating the dynamics of food greenness and brand reputation. Taboubi (2019) explored pricing and advertising investment issues in supply chains, using DGT to analyze how retailers should enhance product promotion in a manufacturer-dominated supply chain.

This research makes three principal contributions. First, unlike prior studies that have analyzed agricultural clusters and logistics in isolation, we conceptualize them as a dynamically coupled complex system. This approach addresses a gap in the literature regarding the internal structure and coupling mechanisms of high-quality development, thereby enriching the theoretical framework for agriculture industrial coordination. Second, we integrate SD with symbiosis (or coupling coordination) theory to construct the first system dynamics model of a symbiotic agricultural-cluster–logistics system. Within this framework, we dissect the feedback loops and dynamic evolution mechanisms of the cluster–logistics–economic growth subsystems. Through an empirical simulation in Jiangsu Province, we reveal their coordinated and balanced development trends under key drivers: policy support, labor allocation, and transportation conditions. These revealed trends and their underlying drivers, in turn, provide a scientific basis for forecasting and evaluating multipolicy packages for regional agricultural advancement. Third, based on a coupling coordination degree model and historical validation, we quantitatively measure the coordination levels of agricultural clusters and logistics across Jiangsu's prefectures. Through sensitivity analysis and PVAR testing, we find heterogeneity in policy responsiveness, market demand, and resource endowments among cities. These findings offer theoretical guidance for optimizing interregional factor allocation and enhancing overall system performance. This study presents new insights for advancing China's agricultural modernization through "place-based, differentiated strategies."

The remainder of this study is organized as follows. Section 2 reviews the literature, systematically synthesizing advances in constructing high-quality development systems and multilevel coupling mechanisms within them. Section 3 introduces the methodology, detailing the SD model's boundary assumptions, causal loop and stock–flow diagramming, data sources, parameter estimation, and validation methods. Section 4 presents the results, including system dynamics simulation of the cluster–

logistics symbiotic system, analysis of its evolutionary mechanisms, and optimization of the model with evaluation of the synergistic effects of policy, labor return, and transportation improvements. Section 5 discusses the findings, interpreting regional disparities and policy implications in light of the model and empirical evidence. Finally, Section 6 concludes and outlines directions for future research.

1. Literature Review

1.1 Current Status of Research on High-Quality Development Systems

SD is a powerful methodology for exploring the dynamic behavior and feedback mechanisms of complex systems. By representing systems in terms of stocks and flows and mapping positive and negative feedback loops, SD offers a tractable quantitative framework for analyzing system evolution and simulating policy interventions (Li et al., 2024). In the context of high-quality development research, scholars have typically conceptualized such development as a multidimensional, interdependent equilibrium structure and employed SD to decompose its internal subsystems and dynamic evolution pathways.

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Figure 1. **Conceptual Framework of the High-Quality Development System with Six Core Dimensions**

As illustrated in *Figure 1*, a prototypical high-quality development system comprises six major dimensions:

(1) Economic development

As the core driver of high-quality development, this dimension supplies the material foundation and stable financial resources essential for other dimensions (Wang et al., 2021).

(2) Market services

By ensuring competitive, well-functioning factor and product markets, this dimension facilitates the efficient allocation and mobility of resources (Dong et al., 2022).

(3) Government governance

Through macro level regulation and public policy instruments, this dimension furnishes the institutional support and safeguards necessary for system-wide operation (Huang et al., 2024).

(4) Social governance

Encompassing social infrastructure and public services, this dimension underpins the balanced co-development of economic and social outcomes (Massey et al., 2016).

(5) Green governance

Emphasizing the integration of ecological civilization and sustainable development, this dimension leverages environmental regulation and technological innovation to achieve a dual win for economy and ecology (Dieng et al., 2017).

(6) Technological innovation

As the fundamental engine of high-quality development, advances in technology and robust innovation networks are pivotal to sustaining long-term economic growth (Diaconu, 2011).

Although prior studies have elucidated the multidimensional nature of high-quality development and the interactions among its constituent dimensions, most literature has focused predominantly on single-dimension measurement and evaluation (Kruk *et al*., 2018). Studies have paid insufficient attention to the structured operational mechanisms and multilayered co-evolution within the system.

To address this gap, recent research advocates for a deep analysis of the dynamic feedback and evolutionary trajectories among dimensions within an SD framework. Bei *et al*. (2018) emphasized that market service and cultural confidence are the external “shell” and internal “core” of high-quality development, respectively. Moreover, cultural confidence—cultivated as the system’s foremost cultural soft power—reinforces intrinsic value alignment and enhances overall system resilience and coordination. Accordingly, this study extends the traditional six-dimensional model by introducing two additional dimensions: market service quality and cultural confidence. It thus constructs a more comprehensive high-quality development framework. Within the SD model, the causal loops and feedback structures of all eight dimensions are systematically mapped to underpin scenario-based projections of system behavior under alternative policy configurations.

1.2 Internal Coupling Mechanisms of the High-Quality Development System

Coupling coordination theory aims to uncover the interaction and synergistic development mechanisms among multiple subsystems within a larger system. At its core, the framework focuses on two key constructs: coupling, which quantifies the strength of mutual influence between subsystems; and coordination, which measures the degree of their orderly alignment (Li *et al*., 2012). In high-quality development research, scholars have typically decomposed the overall system into several interrelated subsystems and then employed a coupling degree C and a coordination degree T to assess the system’s aggregate efficiency and synergy (Cheng *et al*., 2019).

Drawing on the characteristics of its three subsystems—agricultural industry clusters, agricultural logistics, and regional agricultural economy—this study follows the framework proposed by Lu *et al*. (2015) to classify the high-quality development system into three components: the service provider system, which includes the industry clusters, government governance, and social governance; the target achievement system, encompassing agricultural logistics, green governance, and technological innovation; and the growth–momentum system, comprising regional agricultural GDP and market services.

Source: created by the authors.

Figure 2. **Schematic of the Two-Level Coupling of Regional Agricultural High-Quality Development Systems**

Figure 2 presents the two-level coupling model introduced herein. The first-level coupling captures interactions among the three subsystems (e.g., the support the service provider system provides to the target achievement system, and the feedback the growth–momentum system returns to the service provider system). The second-level coupling describes the coordination among different dimensions within each subsystem (e.g., the collaboration between government governance and social governance within the service provider system; the interaction between technological innovation and green governance within the target achievement system; and the symbiosis of economic development and market services within the growth–momentum system.

The common coupled coordination models are:

$$C = \left(\prod_{i=1}^{n} U_i \right)^{1/n}, T = \sqrt{C \times D} \quad , \tag{1}$$

where U_i denotes the normalized composite index of the *i*th subsystem, and D represents the weighted sum of all subsystem weights. where U_i denotes the normalized composite index of the *i*th subsystem, and D represents the weighted sum of all subsystem weights.

Previous studies have applied coupling coordination analysis to China's high-quality development disparities. Peili *et al*. (2018) measured interprovincial differences, finding significant variations in the coupling between supporting services and growth momentum. Yang *et al*. (2020) emphasized that the spatiotemporal evolution of coupling coordination dynamics offers crucial guidance for targeted regional policies. However, these investigations primarily address single-level coupling and pay limited attention to second-level coupling within subsystems, such as the coordination between social services and public safety within government governance or between GDP and employment matching within the economic subsystem.

In summary, existing studies exhibit two principal gaps. First, the multidimensional causal loops and multilevel coupling mechanisms underpinning high-quality development systems have not been fully elucidated. Second, few investigations have examined the coupling and coordination among key dimensions within subsystems, leaving the influence of internal dynamic feedback on the overall system unexplored.

To address these gaps, this study focuses on the symbiotic development of regional agricultural industry clusters and agricultural logistics by constructing an SD model and applying it to Jiangsu Province for simulation and optimization. Drawing on symbiosis theory, we initially clarify the conceptual foundations, driving factors, and interaction mechanisms of regional agricultural clusters and logistics. We then develop causal loop and stock–flow diagrams to delineate the main feedback loops and system structure. We also incorporate empirical data from Jiangsu Province to calibrate parameters and validate the model's reliability. Finally, through scenario-based sensitivity and optimization analyses, we derive targeted policy and practical recommendations to promote coordinated, high-quality development.

2. SD Simulation and Optimization of Symbiotic Relationships

2.1 System Boundaries and Assumptions

Prior to applying SD, defining the system's purpose and the principal issues it will address is essential, thereby clarifying its scope and contents. In this study, the system is designed to achieve the following objectives:

(1) Construct a stock–flow diagram of the symbiotic relationship between regional agricultural industry clusters and agricultural logistics, assign model parameters using relevant data, and perform simulation for trend-based forecasting.

(2) Based on the simulation results and optimization goals, adjust the controllable parameters, compare system behavior before and after these adjustments, and derive feasible policy recommendations to promote coordinated development of clusters and logistics.

The key assumptions underlying our model are:

(1) Regarding agricultural logistics transportation modes, all agricultural logistics will be transported by road. This assumption is made because road transportation remains the main mode of agricultural logistics, and data for other transportation modes are unavailable.

(2) In calculating labor costs, the average cost of the regional labor force is used due to a lack of relevant data, without considering income disparities among different practitioners.

When discussing agricultural logistics, the operation of logistics in agricultural production and business activities is mainly considered, excluding its use in residents' daily lives. The reason is that residents' use of agricultural logistics accounts for a relatively small percentage of the total.

2.2 Causation Analysis

The causal loop diagram forms the foundation of our SD model, succinctly illustrating its logical architecture and the principles governing system behavior. Under the conditions defined above, we identify the qualitative and quantitative parameters of the symbiotic entities. These parameters include cluster output value, sales volume, logistics cost, scale of logistics enterprises, business volume, service pricing, service cost, and operating revenue, as well as environmental factors, such as national regulations and policies, infrastructure development, and talent availability.

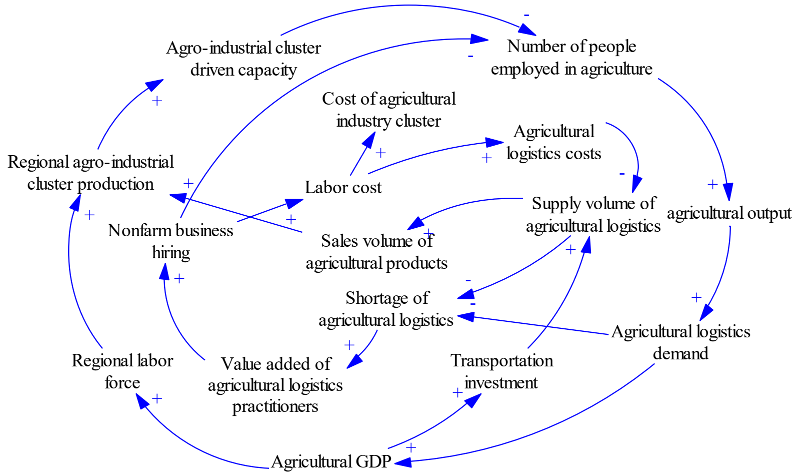

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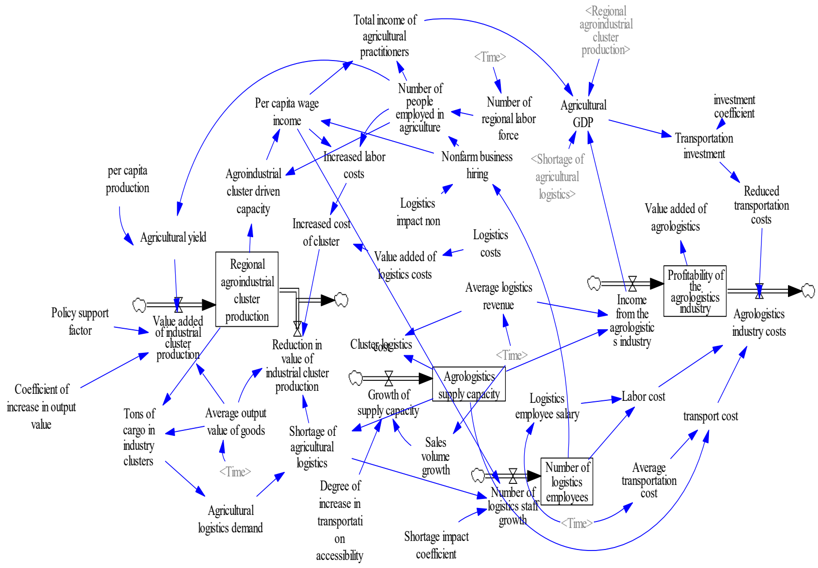
Figure 2. **Causality Diagram**

These elements are integrated into the causal loop diagram presented in *Figure 3*.

2.3 System Flowchart

To analyze the change status of each system element and illustrate in detail the causal relationships among them, we develop the SD flow diagram of the symbiotic system of regional agricultural industry clusters and agricultural logistics, building upon the causality diagram, as shown in *Figure 4*.



Source: created by the authors.

Figure 4. **System Flowchart**

2.4 Overview of the Development of Regional Agricultural Industry Clusters and Agricultural Logistics in Jiangsu Province

Jiangsu Province stands at the forefront of China's regional economic development and possesses a robust agro-economic foundation. Blessed with abundant precipitation and extensive plains, the province offers naturally favorable conditions for agriculture. Historically renowned for its fertile soils and rich biodiversity, Jiangsu has long been one of China’s key grain, cotton, and oilseed production bases. Its diversified agro-ecological endowments underpin a well-integrated farming system where crop cultivation and animal husbandry coexist and reinforce each other. Consequently, the formation and evolution of agricultural industry clusters in Jiangsu provide a highly representative and instructive example for China’s broader agricultural modernization efforts.

Rich natural resources and a strong agricultural base have led to the formation of a comprehensive primary industry structure in Jiangsu Province, China, including crop production, animal husbandry, forestry, and aquaculture. *Table 1* summarizes the province’s aggregate agricultural, forestry, animal husbandry, and fishery output over selected benchmark years, furnishing essential data for a subsequent analysis of cluster–logistics synergy. As shown, total agricultural output in Jiangsu has risen steadily; despite uneven growth across subsectors, the overall upward trajectory confirms that the province’s agriculture remains on a robust growth path. In recent years, local governments at all levels have leveraged distinct regional specialties to guide and cultivate characteristic agricultural clusters, effectively converting inherent resource advantages into differentiated industrial strengths. Notable examples include the development of Baoying lotus, Yangzhou goose, Xinghua scallion, Jiangdu floriculture, Shuyang horticulture, and Funing pig farming clusters or their embryonic forms. These initiatives have significantly enhanced local competitiveness and improved economic returns.

Table 1. Production value of agriculture, forestry, animal husbandry, and fishery in Jiangsu Province

Year	Total production (Billion yuan)	Value of agricultural production (Billion yuan)	Value of forestry production (Billion yuan)	Value of pastoral production (Billion yuan)	Value of fisheries production (Billion yuan)	Value of agricultural services production (Billion yuan)
The end of the “11th Five-year” period	4283.21	2256.99	78.12	921.90	805.25	220.95
The end of the “12th Five-year” period	6980.37	3675.87	129.09	1257.92	1517.51	399.97
The end of the “13th Five-year” period	7951.7	4458.2	158.6	1301.4	1192.8	840.7

Source: created by the authors.

Situated in the central coastal region of eastern Mainland China, Jiangsu Province is a pivotal core of the Yangtze River Delta. The province’s topography is predominantly flat, interlaced with extensive waterways, and endowed with abundant water resources. The Yangtze River traverses the province from west to east, whereas the Beijing–Hangzhou Grand Canal bisects it north to south; in addition, Jiangsu’s coastline extends 954 km. Road and rail networks among its 13 prefecture-level cities are highly developed, forming a “5 vertical × 9 horizontal × 5 link” expressway grid, and the “villages-connected” rural road program is effectively complete. These transportation improvements have substantively enhanced agricultural product distribution and, in parallel, alleviated rural unemployment pressure.

Table 2 presents the number of logistics employees in Jiangsu’s rural areas over key years. Although logistics employment has grown year-on-year, the rate of increase does not fully align with overall regional economic expansion. This divergence suggests that agricultural logistics employment remains constrained by multiple factors, simultaneously indicating significant untapped potential within Jiangsu's logistics sector. This identified divergence and untapped potential therefore necessitates further enhancements in policy support, technological innovation, and service frameworks.

Table 2. Number of logistics employees in rural areas

Year	The end of the "11th Five-year" period (Ten thousand people)	The end of the "12th Five-year" period (Ten thousand people)	The end of the "13th Five-year" period (Ten thousand people)
Number of logistics employees	111.74	114.50	230

Source: created by the authors.

As one of China's leading agricultural provinces, Jiangsu consistently ranks among the top national producers of fruits, vegetables, meat, and aquaculture products. In 2022, the province's vegetable output reached 59.508 million tons (up 1.2%), accounting for 77.5% of total principal cold chain products; fruit output was 9.523 million tons (up 0.6%), representing 12.4%; aquaculture output totaled 4.815 million tons (down 2.3%), or 6.3%; and meat output stood at 3.156 million tons (down 2.0%), or 4.1%.

Over years of sustained investment, Jiangsu has progressively strengthened its cold chain logistics infrastructure. A network of modern refrigerated warehouses has been established, and new cold chain technologies have been widely adopted. These advances have culminated in an integrated system that centers on cold chain storage and extends through processing, transportation, distribution, and ancillary facilities. According to data from the Cold Chain Committee of the China Federation of Logistics and Purchasing, Jiangsu's total cold storage capacity expanded from 2.80 million tons in 2016 to 5.20 million tons in 2023—a growth of 85.7%. These figures demonstrate significant interim progress in enhancing agricultural logistics, particularly cold chain capabilities, while underscoring the remaining scope for further expansion and refinement.

2.5 Parameter Estimation and Validity Test

The horizontal, rate, and auxiliary variables in this model are shown in *Table 3*.

Table 3. Description of variables

Variables	Type	Definition
Agricultural GDP	L	Annual gross product of agriculture
Regional agro-industrial cluster production	L	Annual GDP of agro-industrial clusters in the regional context
Profitability of the agro-logistics industry	L	Total annual profit of the agro-logistics industry
Number of logistics employees	L	Annual number of employees in the regional logistics industry
Agro-logistics supply capacity	L	Annual supply of agro-logistics
Value added of industrial cluster production	R	Annual value added of regional agro-industrial clusters
Reduction in value of industrial cluster production	R	Impact value of impediments to regional agricultural industry cluster development
Income from the agro-logistics industry	R	Annual income from the agro-logistics industry
Agro-logistics industry costs	R	Total annual cost of the agro-logistics industry
Growth of supply capacity	R	Value added of annual supply of agro-logistics
Number of logistics staff growth	R	Annual value added of the number of logistics employees

Table 3 (*continuation*). Description of variables

Variables	Type	Definition
Agro-industrial cluster driven capacity	A	Capacity of agro-industrial clusters to enhance per capita income
Per capita wage income	A	Level of per capita income of the labor force in the region
Value added of agro-logistics	A	Value added of income from agro-logistics
Value added of logistics costs	A	Increase in logistics costs for agricultural industry clusters
Logistics costs	A	Logistics costs of regional agro-industrial clusters
Nonfarm business hiring	A	Nonfarm business employment in the area
Number of people employed in agricul-ture	A	Number of persons engaged in the agricultural industry in the region
Tons of cargo in industry clusters	A	Annual production of products in regional agro-industrial clusters
Policy support factor	A	Coefficient measuring the effects of government policies on value added of industrial cluster
Degree of increase in transportation accessibility	A	Effect of transportation accessibility on the growth of agro-logistics supply capacity
Number of regional labor force	A	Total labor force in the region
Logistics impact nonfarm coefficients	A	Effect of the number of logistics workers on the number of employees in nonagricultural firms

Notes: L denotes state variables, R denotes rate variables, and A denotes auxiliary variables.

Source: created by the authors.

The main parameter estimation methods used in the model are as follows:

(1) Parameter equations are determined by data analysis and application of regression fitting through SPSS software;

(2) Parameter equations are identified via mathematical derivation;

(3) Random, conditional, and table functions in Vensim software are applied for description. The initial time of this model is 2010, and the simulation times are 2010–2024 and 2025–2033. The initial values are shown in *Table 4*.

Table 4. Description of variables

Variable name	Initial value	Unit
Agricultural GDP	4283.21	Billion yuan
Regional agro-industrial cluster production value	1927.44	Billion yuan
Profitability of the agro-logistics industry	3.23	Billion yuan
Number of logistics employees	111.74	Million people
Agro-logistics supply capacity	2490.21	Million tons

Source: created by the authors.

In the SD modeling of the symbiotic relationship between regional agricultural industry clusters and agricultural logistics, several key parameters lack directly observable data and must therefore be estimated through the processing and transformation of raw data. The estimation methods for several core variables are described below:

(1) Cluster-induced income effect: This variable measures the effect of the agricultural industry cluster on regional per capita income, typically influenced by cluster output value and employment in agriculture. A curve-fitting analysis in SPSS yielded a high coefficient of determination (R^2 = 0.990), indicating excellent model fit. Accordingly, the following regression equation is used to estimate the cluster's income-inducing effect:

Cluster-induced Income Effect = 0.0001 × Cluster Output Value − 0.002 × Agricultural Employment + 214.265.

(2) Per capita wage income: Defined as the average wage level of the regional labor force, this variable depends on the cluster-induced income effect and nonagricultural employment. Curve-fitting in SPSS produced R^2 = 0.957, confirming the model's predictive validity. The estimated equation is:

Per Capita Wage Income = (Cluster-induced Income Effect × Nonagricultural Employment) − 37.898.

(3) Value added of agricultural logistics This variable represents the year-over-year increase in the agricultural logistics sector's output value and is closely related to logistics industry profits. The SPSS fit yielded R^2 = 0.995, indicating an extremely strong linear relationship. The calculation formula is:

Value Added of Agricultural Logistics = 0.807 × Logistics Profit − 1.32.

(4) Increase in logistics costs: Representing the year-over-year change in logistics costs within regional clusters, this variable is crucial for tracking cost fluctuations. The linear regression model achieved R^2 = 0.994, demonstrating high explanatory power. Thus,

Increase in Logistics Costs = 0.242 × Total Logistics Costs − 1.32.

(5) Nonagricultural employment: Defined as the total number of rural workers employed by nonagricultural enterprises—including those in agricultural logistics—this variable's regression model returned R^2 = 0.836. Although lower than for other variables, it remains acceptable for estimation. The formula is:

Nonagricultural Employment = (Logistics Employment × 26.104) − 1125.1,

where 26.104 is the logistics-to-nonagricultural employment coefficient.

The construction of these variable relationships and system diagrams does not guarantee practical applicability. Model validity must be confirmed through structural verification, sensitivity analysis, and historical data validation.

Sensitivity analysis evaluates whether the model is overly responsive to parameter changes. Structural stability can be assessed by perturbing key parameters and observing output volatility. Excessive output swings indicate the need for parameter reestimation or structural adjustments. Historical data validation compares simulated outputs against observed data over the calibration period.

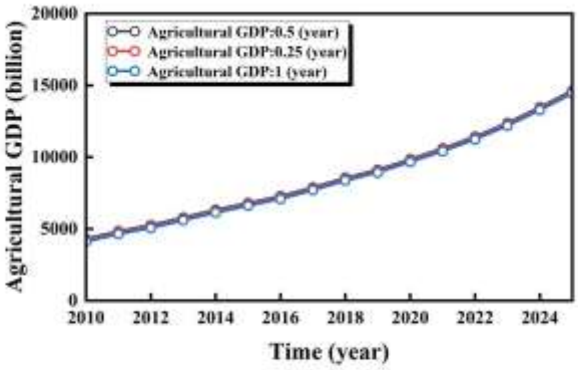


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Figure 5. **Sensitivity Test**

In this study, agricultural GDP from 2010 to 2024 is simulated under three time-step intervals (0.25, 0.5, and 1 year). As shown in *Figure 5*, the GDP trajectories exhibit minimal variation across time steps, demonstrating model stability and low sensitivity, thereby confirming the model's readiness for further analysis and application.

Table 5. Historical test

Year	Real agricultural GDP value (Billion yuan)	Simulated agricultural GDP value (Billion yuan)	Ratio	Number of actual logistics employees (Million people)	Number of simulation logistics employees (Million people)	Ratio
2010	4283.20	4283.2	0	111.74	111.74	0
2011	5217	4798.9	8.01%	113.15	111.66	1.32%
2012	5781.5	5314.5	8.08%	114.55	112.44	1.84%
2013	6124.3	5831.8	5.02%	114.56	113.14	1.24%
2014	6402.8	6330.8	1.12%	114.29	113.76	0.46%
2015	6980.4	6837.1	2.05%	114.50	114.12	0.33%
2016	7179.0	7331.4	2.12%	113.94	114.33	0.34%
2017	7161.2	7489.4	4.58%	114.87	114.73	0.12%
2018	7192.5	7540.2	4.83%	115.12	115.89	0.67%
2019	7503.2	7677.8	2.33%	116.61	116.08	0.46%
2020	7951.7	8121.5	2.14%	116.99	117.85	0.74%
2021	8279.7	8399.3	1.44%	120.54	119.05	1.24%
2022	8733.8	8886.9	1.75%	123.32	121.44	1.52%
2023	8935.5	9127.3	2.15%	124.67	122.68	1.60%
2024	9284.6	9562.2	2.99%	125.88	123.89	1.58%

Source: created by the authors.

Historical validation is the most critical step in model testing. It involves comparing the simulation outputs against observed data to calculate error rates and determine whether they fall within acceptable bounds, thereby confirming the model's fidelity to real-world behavior. *Table 5* presents the validation results for agricultural GDP and logistics employment from 2010 to 2024. The simulated agricultural GDP values deviate from actual figures by no more than 8.5%, and the simulated logistics employment differs from observed data by less than 2%. Both error rates are well within the conventional 10% threshold for

SD models, thereby demonstrating that the agricultural cluster–logistics symbiotic model exhibits satisfactory historical validity.

3. Results Analysis

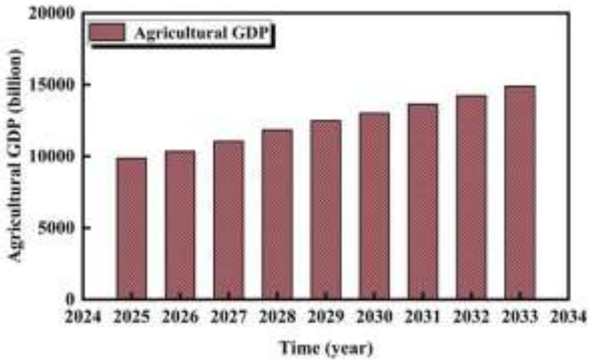
3.1 Simulation and Analysis of Symbiotic SD of Regional Agricultural Clusters and Agricultural Logistics

The forecast results of agricultural GDP in Jiangsu Province, China for the years 2025–2033 are shown in *Table 6* and *Figure 6*, showing that the agricultural GDP of Jiangsu Province grows steadily. Moreover, by 2033, the agricultural GDP of Jiangsu Province will reach 14897.9 billion yuan, indicating that the agriculture in Jiangsu Province is still in a steady upward stage.

Table 6. Forecast results of agricultural GDP in Jiangsu Province

Year	Predicted results (Billion yuan)
2025	9876.7
2026	10345.9
2027	11048.1
2028	11841.6
2029	12485.3
2030	13001.5
2031	13645.6
2032	14235.5
2033	14897.9

Source: created by the authors.



Source: created by the authors.

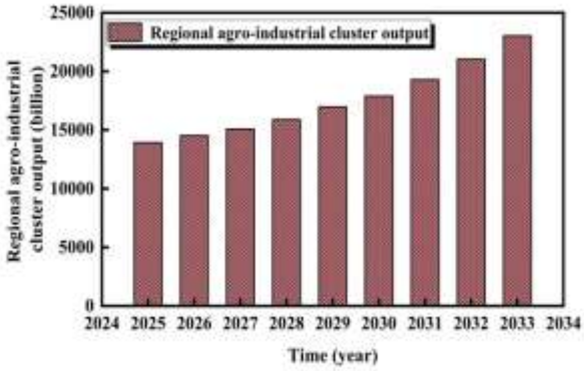
Figure 6. **Forecast of Agricultural GDP in Jiangsu Province**

The forecast results of the output value of regional agricultural clusters, as well as the cargo tonnage of clusters in Jiangsu Province, China from 2025 to 2033, are shown in *Table 7* and *Figure 7 and Figure 8*. The results show that the output value of regional agricultural industry clusters and the tons of goods in the clusters show a steady rising trend. However, the output value rises more vigorously, and, relatively speaking, the change curve of the tons of goods is relatively flat. That is, the development of regional agricultural industry clusters will remain one of the driving forces of agricultural development in the coming years.

Table 7. Forecast of regional agro-industrial clusters

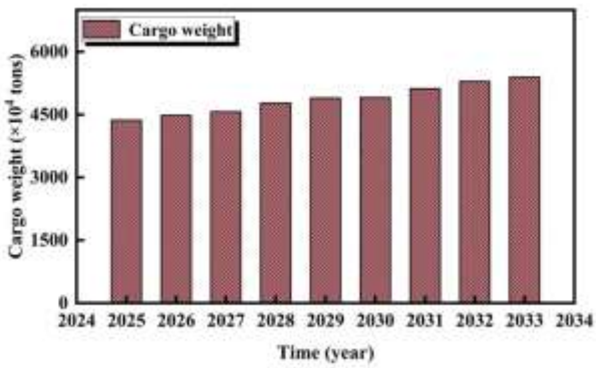
Year	Cluster production value (Billion yuan)	Cargo weight (Million tons)
2025	13930.9	4367.1
2026	14521.2	4482.4
2027	15083.3	4566.7
2028	15892.2	4772.1
2029	16968.1	4895.6
2030	17893.4	4905.8
2031	19300.2	5118.7
2032	21045.8	5290.9
2033	23033.9	5392.0

Source: created by the authors.



Source: created by the authors.

Figure 7. **Forecast of Agricultural GDP in Jiangsu Province**



Source: created by the authors.

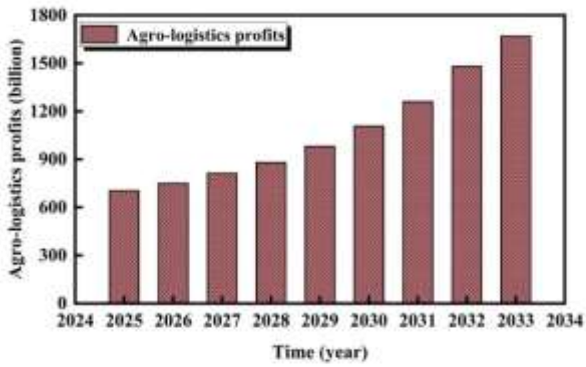
Figure 8. **Tons of Cargo in Industrial Clusters**

Table 8 and *Figures 9–11* present the predicted values for agricultural logistics profit, agricultural logistics supply capacity, and the number of logistics employees in Jiangsu Province, China from 2025 to 2033. The results show that in the next few years, agricultural logistics profits are expected to increase rapidly, whereas the growth rate of agricultural logistics supply capacity is gradually slowing down. This trend suggests that a new stage of development has been reached, signaling rapid advancement of agricultural logistics in Jiangsu Province. Moreover, the number of people working in agricultural logistics shows fluctuating changes, experiencing a slow decline followed by a subsequent rise, with relatively small changes overall. This result further suggests that the number of people working in agricultural logistics remains relatively stable.

Table 8. Forecast of agricultural logistics development in Jiangsu Province

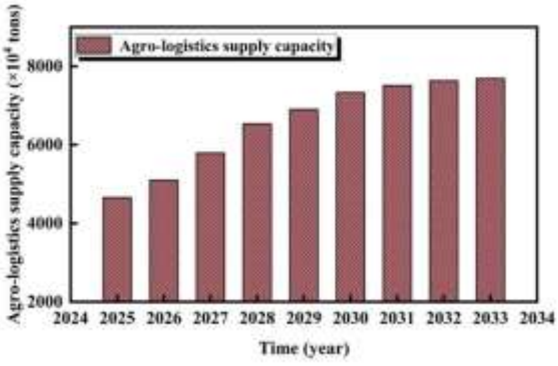
Year	Profitability (Billion yuan)	Supply capability (mln. tons)	Number of employees (mln people)
2025	704.36	4655.03	126.18
2026	750.05	5095.43	131.35
2027	812.23	5793.32	140.89
2028	880.91	6534.31	148.79
2029	980.35	6902.01	145.21
2030	1106.72	7329.55	141.63
2031	1259.94	7510.11	139.88
2032	1479.21	7629.36	141.99
2033	1669.35	7689.39	143.08

Source: created by the authors.



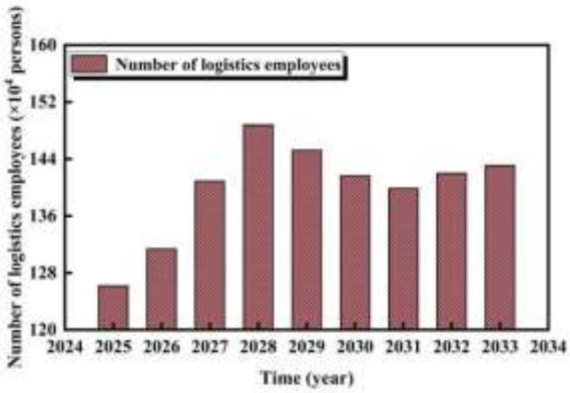
Source: created by the authors.

Figure 9. **Agri-Logistics Profit Forecast**



Source: created by the authors.

Figure 10. **Forecast of Agri-Logistics Supply Capacity**



Source: created by the authors.

Figure 11. **Forecast of the Number of Logistics Employees**

According to the base calculation model of symbiosis degree and symbiosis coefficient given by Wang *et al*. (2019), M_i (*i* belong to *I*) is assumed to be the symbiosis unit of the regional agricultural industry cluster, *I* is the set of the number of symbiosis units of the regional agricultural industry cluster, L_j (*j* belong to *J*) is the symbiosis unit of the agro-logistics industry, and *J* is the set of the number of symbiosis units of the agro-logistics industry. The qualitative covariates corresponding to the two symbiotic units are denoted as Z_i and Z_j, and the symbiotic degree elasticity of the system can be expressed as:

$$\theta_{M_i L_i} = \left(\frac{dZ_i}{Z_i}\right) / \left(\frac{dZ_j}{Z_j}\right). \quad (2)$$

Assuming that the value added of the regional agro-industrial cluster is denoted as V_M and the value added of the agro-logistics industry is denoted as V_L, the degree of symbiosis θ_{ML} of the regional agro-industrial cluster to the agro-logistics industry is defined as follows:

$$\theta_{ML} = \frac{dv_M / v_M}{dv_L / v_L}. \quad (3)$$

Conversely, the degree of symbiosis θ_{LM} of the agro-logistics industry on the agricultural cluster is defined as follows:

$$\theta_{LM}=\frac{dv_L / v_L}{dv_M / v_M}. \quad (4)$$

According to the results of the above simulation data calculated by the formula, $\theta_{ML} \neq \theta_{LM} > 0$. During the period of 2025–2033, the regional agricultural clusters and agricultural logistics in Jiangsu Province, China, are in a positive asymmetric reciprocal symbiosis mode, and the regional agricultural logistics industry has a greater effect on agricultural logistics.

3.2 Optimization of Symbiotic Model of Regional Agricultural Industry Cluster and Agricultural Logistics

Based on the calibrated model and the actual conditions of cluster–logistics symbiosis, sensitivity analyses are conducted by adjusting key driving variables to evaluate their optimization effects on the co-development system. In one scenario, the policy support coefficient is increased from approximately 0.05 to 0.20. *Table 9* and *Figures 12–13* summarize the resulting changes in the cluster output value and logistics employment.

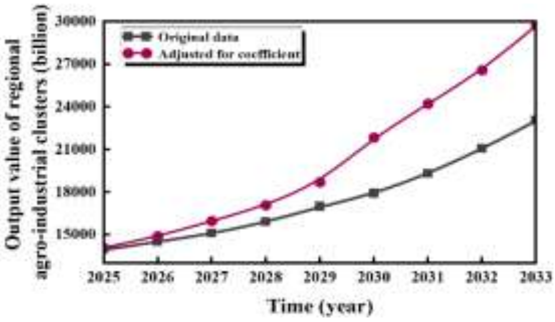
Table 9. Simulation data variation

	Production value of regional agricultural clusters (Billion yuan)			**Number of people employed in agricultural logistics (Million people)**		
Year	**Initial data**	**Adjusted for coefficient**	**Rate**	**Initial data**	**Adjusted for coefficient**	**Rate**
2025	13930.9	14085.7	1.11%	126.18	132.22	4.79%
2026	14521.2	14893.2	2.56%	131.35	142.56	8.53%
2027	15083.3	15968.8	5.87%	140.89	150.83	7.06%
2028	15892.2	17078.3	7.46%	148.79	158.31	6.40%
2029	16968.1	18702.1	10.22%	145.21	162.89	12.18%
2030	17893.4	21845.9	22.09%	141.63	156.78	10.70%
2031	19300.2	24222.6	25.50%	139.88	151.33	8.19%
2032	21045.8	26578.9	26.29%	141.99	155.09	9.23%
2033	23033.9	29731.1	29.08%	143.08	157.88	10.34%

Source: created by the authors.

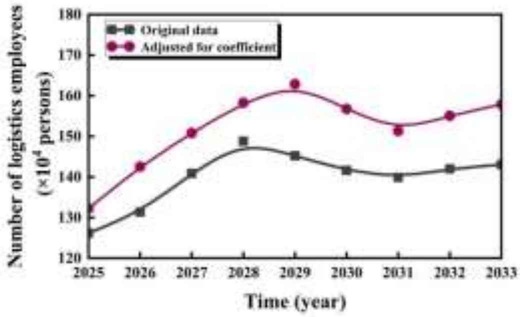
When the policy support coefficient rose by 0.15 (i.e., from 0.05 to 0.20), the average increase in agricultural industry cluster output was approximately 14.5%. Although the overall trajectory of the simulation curves remained qualitatively similar, the rate of growth accelerated appreciably. Logistics employment experienced an average change of about 8.6%. Notably, following the policy support increase, the initial decline in logistics employment was more pronounced, whereas the model's terminal point ultimately exhibited an upward trend.

Mechanistically, stronger policy support bolsters cluster output, which, in turn, elevates logistics demand. This increased demand, by exacerbating the shortfall in logistics capacity, creates upward pressure on employment. The close alignment between rising cluster demand and simulated employment trends underscores the model's consistency with real-world dynamics.



Source: created by the authors.

Figure 12. **Variations in the Output Value of Regional Agro-Industrial Clusters**



Source: created by the authors.

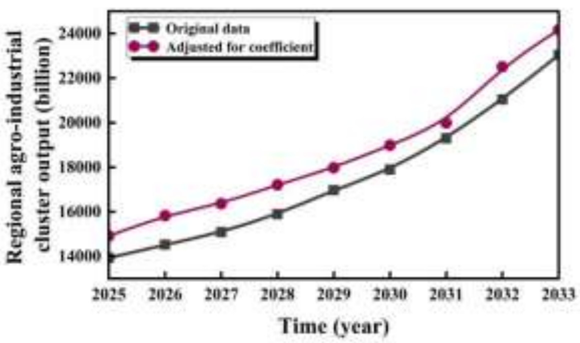
Figure 13. **Number of People Working in Agro-Logistics**

After increasing the original number of regional labor force by 2%, the simulated changes in the output value of regional agricultural clusters are shown in *Table 10* and *Figure 14*. After the growth of the number of regional labor force, the change in the output value of the regional agricultural industry cluster was more obvious, and a stable increase was observed in the output value relative to the output value before the change during the period of 2025–2033, with an average growth rate of about 6.72%. However, the growth amount was gradually less, indicating that the trend of the change tends to be stable. In addition, after adjusting the number of regional labor force, the profit of agricultural logistics, agricultural GDP, and the supply capacity of agricultural logistics within the model increased to a certain extent.

Table 10. Amount of change with increased labor force

Year	Initial data	Adjusted for coefficient	Rate
2025	13930.9	14919.8	7.1%
2026	14521.2	15832.6	9.03%
2027	15083.3	16367.2	8.51%
2028	15892.2	17212.4	8.31%
2029	16968.1	17977.5	5.95%
2030	17893.4	18988.9	6.12%
2031	19300.2	19989.9	3.57%
2032	21045.8	22512.3	6.97%
2033	23033.9	24165.5	4.91%

Source: created by the authors.



Source: created by the authors.

Figure 14. **Variations in Regional Agro-Industrial Cluster Output at Different Levels of Transportation Accessibility**

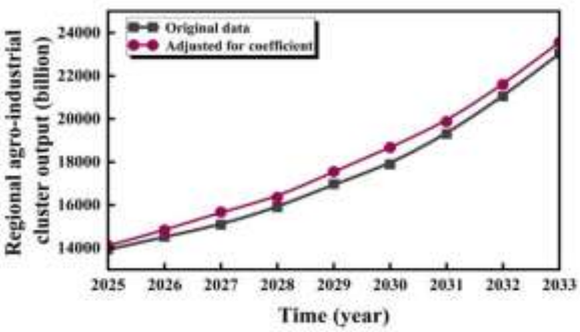
When the transport accessibility coefficient was adjusted from its original random range of 0.01–0.10 to 0.06–0.15, the simulated responses of regional agricultural clusters and agricultural logistics supply capacity are summarized in *Table 11* and *Figures 15 and 16*. The results show that enhancing transport accessibility yields a modest but consistent increase in cluster output, with an average growth rate exceeding 2%. Agricultural logistics supply capacity likewise increases by approximately 2% on average, with gains remaining stable over time.

These findings indicate that although the magnitude and timing of effects vary across subsystems, overall enhancements in transport accessibility drive more stable, synchronized growth throughout the cluster–logistics symbiotic system. Notably, even under the improved transport scenario, the system retains its asymmetrically reciprocal symbiosis mode. However, the influence of logistics on cluster performance is measurably stronger than in the preoptimization baseline.

Table 11. Variation of simulation data with different levels of transportation accessibility

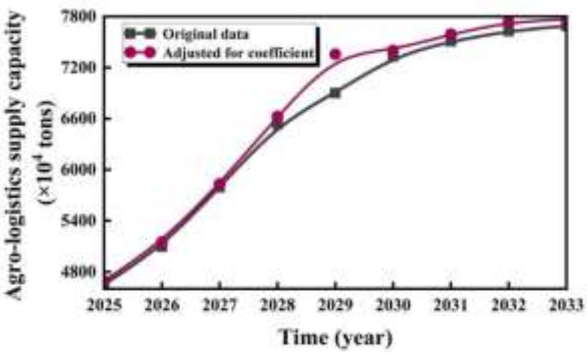
	Production value of regional agricultural clusters (Billion yuan)			Agricultural logistics supply capacity (Million tons)		
Year	**Initial data**	**Adjusted for coefficient**	**Rate**	**Initial data**	**Adjusted for coefficient**	**Rate**
2025	13930.9	14112.3	1.30%	4655.3	4695.4	1.51%
2026	14521.2	14836.7	2.17%	5095.4	5151.2	1.88%
2027	15083.3	15672.4	3.91%	5793.3	5834.6	1.92%
2028	15892.2	16357.9	2.93%	6534.3	6625.4	2.16%
2029	16968.1	17555.1	3.46%	6902.0	7356.9	2.24%
2030	17893.4	18672.5	4.35%	7329.6	7401.2	2.07%
2031	19300.2	19875.6	2.98%	7510.1	7593.4	2.17%
2032	21045.8	21598.8	2.63%	7629.4	7734.3	2.16%
2033	23033.9	23554.3	2.26%	7689.4	7767.3	2.31%

Source: created by the authors.



Source: created by the authors.

Figure 15. **Variations in the Output Values of Regional Agro-Industrial Clusters at Different Levels of Transportation Accessibility**



Source: created by the authors.

Figure 16. **Variations in Agro-Logistics Supply Capacity at Different Levels of Transportation Accessibility**

4. Discussion

Through SD simulation, scenario-based optimization, multilevel coupling analysis, and Granger causality testing of the agricultural cluster–logistics symbiotic system in Jiangsu Province, China, this study generates theoretical insights and practical guidance for high-quality, coordinated regional agricultural development. The following content expands on this discussion.

First, in terms of system modeling, this study's dynamic coupling perspective complements the network and value chain development framework proposed by Li *et al*. (2010), which is based on the division of labor and specialization within industrial clusters. The SD model effectively reproduces the dynamic feedback mechanism among the three subsystems of cluster–logistics–economic growth. Historical validation shows that the simulation errors for agricultural GDP and the number of logistics employees from 2010 to 2024 are kept within 8.5% and 2%, respectively (*Table 5*). This result demonstrates that the causal loop and flowchart are structured appropriately. Furthermore, negligible changes in agricultural GDP across different simulation time steps (*Figure 1*) confirm the system's low sensitivity and stability. These results indicate that SD, as a tool for capturing the synergistic evolution of regional agriculture, not only can reveal the lagged and cumulative effects of policy or external shocks on clusters and logistics but also provide a "virtual experiment" platform for policymakers. This platform helps assess how varying time lags and intervention intensities affect overall system performance. Different from Jiang *et al*. (2021), who focused on structural analysis of sustainable synergy between industrial clusters and the logistics sector, our work further supplements the simulation pathways of their dynamic evolution and feedback mechanisms. Thus, this study expands the temporal dimension of modeling for agricultural symbiotic systems.

Second, the scenario optimization experiments delineate the differential effects of three primary pathways: policy support, labor return, and transportation improvement. When the policy support coefficient is raised to 0.20, the cluster output value and the number of logistics employees increase by an average of approximately 14.5% and 8.6%, respectively (*Table 9; Figures 10–11*). This result indicates that financial subsidies and industrial assistance can rapidly trigger positive feedback in the system. By contrast, a 2% increase in labor return yields a 6.72% rise in cluster output value (*Table 10; Figure 12*), highlighting the essential role of human resources in sustaining agricultural cluster vitality and logistics service provision. Enhancing transportation accessibility leads to an average 2% increase in cluster output and logistics supply capacity (*Table 11; Figures 13–16*), underscoring the indispensability of infrastructure improvements for stabilizing system efficiency. Compared with Zhang *et al*. (2024), who studied rural integrated development promotion through digital empowerment, this study reveals the asymmetric responses of human resources, policies, and transportation within the symbiotic network of industrial clusters and logistics. Thus, this study provides a quantitative basis for refining policy design.

Third, multilevel coupling and Granger causality analysis highlight regional differences and the diversity of dynamic mechanisms. The PVAR model test shows that in economically developed eastern regions, bidirectional dynamic feedback exists between agricultural clusters and logistics supply capacity. Here, cluster value-added drives logistics expansion, and logistics improvements, in turn, strengthen cluster capacity. Conversely, the central and western regions exhibit a unidirectional "cluster–logistics" transmission, indicating that their logistics systems have not yet formed a mature self-sustaining mechanism. This study not only supplements the "multilayered interactivity" feature mentioned by Niu *et al*. (2023) in the context of coordinated symbiosis pathways between industrial development and the environment but also provides practical insights for upgrading pathways in the central and western regions. Specifically, the industrial foundation must be consolidated while accelerating the construction of logistics autonomous capabilities to break the pattern of unidirectional dependence.

Conclusions

Main Findings

This study takes the symbiotic relationship between regional agricultural industry clusters and agricultural logistics as its research entry point. Moreover, it deeply analyzes the main feedback loops and influencing links within the system. Through causal relationship analysis and SD modeling, it explores the symbiotic development of agricultural industry clusters and agricultural logistics in Jiangsu Province, China. The key conclusions are as follows:

(1) First, the simulation results indicate that from 2025 to 2033, Jiangsu's agricultural GDP, agricultural logistics profits, and cluster output values will all exhibit continuous upward trajectories. This result demonstrates a robust outlook for the co-development of regional agricultural clusters and logistics

(2) Second, the model is calibrated using Jiangsu's empirical data, enabling the derivation of a policy support coefficient and the comparison of simulation scenarios. The results show that strengthening policy support can boost cluster output by 29.08% and logistics employment by 10.34% by 2033. This finding underscores the significant catalytic effect of government intervention on the growth of the joint cluster–logistics systems.

(3) Third, a 2% increase in the regional labor force leads to a 4.91% higher cluster output by 2033, whereas improvements in transport accessibility raise cluster output and logistics capacity by approximately 2% each. These findings highlight the indispensable contributions of human capital and infrastructure enhancements to the synergistic advancement of agricultural clusters and logistics.

Although this study provides a comprehensive analysis within its scope, certain limitations remain. Future research should incorporate additional complexities, such as the influence of leading enterprises within clusters and the geographic distribution of labor, to further refine the system model. As agricultural clusters and logistics continue to evolve together, future works must explore the potential of optimized policies, technological innovation, and infrastructure investment to drive deeper integration and sustain high-quality, symbiotic development.

Management Implications

Based on the model simulations and scenario analyses, the following policy and managerial recommendations are proposed for governmental authorities and industry stakeholders:

(1) First, when the policy support coefficient is raised from 0.05 to 0.20, the simulation projects average increases of approximately 14.5% in agricultural cluster output and 8.6% in logistics employment. However, regional responses to policy stimuli vary significantly. Therefore, maintaining an overall level of support requires designing differentiated subsidy and fiscal incentive schemes for central and western provinces, as well as relatively underdeveloped areas. Prioritizing cluster cultivation and logistics network development in these underdeveloped regions will help narrow interregional coupling coordination gaps and bolster the system's overall synergistic efficiency.

(2) Second, the model indicates that a 2% increase in rural labor supply yields an average of 6.72% uplift in cluster output, alongside concurrent gains in logistics profits and capacity. This finding underscores the importance of enhancing rural workforce skills and stabilizing employment expectations to activate

the system's endogenous dynamism. Public service platforms for "return home entrepreneurship and vocational training" must be established. In addition, support should be provided for the growth and branding of social service organizations and third-party logistics providers. Through industry–academia–research partnerships and certification systems, the professional qualifications of logistics personnel can be elevated. Social organizations can also be incentivized to assume greater operational and technical support roles across production, processing, and distribution. These measures will advance the symbiosis from its current asymmetrical reciprocity toward a more balanced, mutually beneficial model.

(3) Third, scenario simulations where the transport accessibility coefficient is raised to the 0.06–0.15 range show roughly 2% gains in cluster output and logistics supply capacity. This result demonstrates the stabilizing effect of infrastructure improvements on system performance. To optimize these benefits, collaboration between government and industry is recommended to expedite the construction of high-efficiency transport corridors and cold chain logistics nodes linking production zones to major consumer markets. Adopting a "logistics park and intelligent management" model with features such as real-time temperature monitoring, dynamic dispatching, and big data analytics can create an end-to-end smart logistics network covering "field collection–distribution" operations. Such dual investments in physical infrastructure and digital capabilities will synchronously enhance the coordinated effectiveness of agricultural clusters and logistics systems.

Research Limitations and Perspectives

Although this research model can reproduce the macro level interaction between agriculture and logistics in Jiangsu Province, China, it has several limitations. First, the model is mainly based on a single region (Jiangsu Province, China) and lacks cross-provincial comparative validation. Second, it does not sufficiently consider the differentiated behaviors of leading enterprises within clusters or changes in market structure. Finally, many parameters in the simulation are adjusted as single factors, and future research can introduce multifactorial linkages and nonlinear interaction terms.

Future simulations can be refined in several directions. First, the research object can be expanded from Jiangsu Province (a single province) to multiple provinces in China, enabling horizontal regional comparisons. Second, the behavior of micro level enterprise actors and market competition mechanisms can be incorporated to enhance the model's realism. Third, big data and machine learning technologies can be integrated to explore nonlinear mechanisms in the coupling and coordination process. These advancements can help guide more targeted pathways for achieving high-quality development in regional agriculture.

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SIMBIOTINIAI VYSTYMOSI RYŠIAI TARP REGIONINIŲ ŽEMĖS ŪKIO PRAMONĖS KLASTERIŲ IR ŽEMĖS ŪKIO LOGISTIKOS

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Santrauka. Esant koordinuotai pramonės plėtrai, tiekimo grandinių plėtra ir pramoninių ryšių stiprinimas tapo pagrindiniais modernizacijos veiksniais atnaujinant šiuolaikinį žemės ūkio sektorių. Tačiau vis dar stokojama tyrimų, nagrinėjančių regioninių žemės ūkio pramonės klasterių ir logistikos sistemų dinaminio, simbiotinio vystymosi mechanizmus bei jų optimizavimo strategijas, o tai kliudo užtikrinti aukštos kokybės integruotą plėtrą. Siekiant paskatinti integruotą regioninių žemės ūkio klasterių ir logistikos sistemų vystymąsi, šiame tyrime sukurtas sisteminės dinamikos modelis, paremtas simbiozės teorijos principais. Modelis pritaikytas Jiangsu provincijos (Kinija) atvejui, siekiant analizuoti grįžtamojo ryšio mechanizmus ir klasterio bei logistikos simbiotinės sistemos bendrosios evoliucijos trajektorijas.

Pirmiausia buvo apibendrintos simbiotinės sistemos sudedamosios dalys, aplinkos veiksniai ir sąveikos modeliai. Remiantis apibendrinimu buvo sudarytos priežastinių ryšių ir atsargų-srautų diagramos. Antra, atlikus parametrų kalibravimą ir patikimumo testavimą su istoriniais duomenimis, buvo atliktos scenarijų simuliacijos. Galiausiai įvertintas politikos paramos, darbo jėgos grįžimo ir transporto infrastruktūros gerinimo poveikis sistemos veikimui.

Rezultatai atskleidė, kad Jiangsu žemės ūkio BVP iki 2025 m. pasieks 1459,53 mlrd. juanių. Politikos paramos koeficiento padidinimas iki 0,20 gali padidinti klasterio produkcijos vertę ir logistikos užimtumą atitinkamai 3,92 % ir 3,50 %. 2 % darbo jėgos pasiūlos augimas lemia 17,44 % produkcijos vertės padidėjimą, o pagerėjęs transporto prieinamumas padidina klasterio produkcijos vertę ir logistikos pajėgumus atitinkamai 3,19 % ir 2,19 %. Be to, nuolatinis kaimo darbo jėgos nutekėjimas ir logistikos pasiūlos bei paklausos disbalansas išryškėja kaip pagrindiniai veiksniai, ribojantys integruotą plėtrą. Gauti rezultatai ne tik leidžia pateikti teorines gaires regioninių išteklių paskirstymo optimizavimui ir simbiotinės sistemos veikimo tobulinimui, bet ir siūlo naujų įžvalgų, kaip skatinti Kinijos žemės ūkio modernizaciją, taikant vietos sąlygomis pagrįstas, diferencijuotas plėtros strategijas.

Reikšminiai žodžiai: regioninis žemės ūkio pramonės klasteris; žemės ūkio logistika; simbiotiniai santykiai; sistemos dinamika.