Simulation Study on the Policy of Coordinated Development of Agriculture and Agricultural Product Logistics in Sichuan Province

Kailun He¹,a, Xin Huang¹,b

¹School of Management, Chongqing University of Technology, Chongqing 400054, China
²hekailun@cqut.edu.cn, bhuangxin19990911@163.com

Abstract: This paper utilises the system dynamics theory to develop a simulation model of the agricultural and agricultural product logistics system in Sichuan Province. The coordinated development policy of the agricultural and agricultural product logistics in Sichuan Province is analysed through simulation by adjusting the proportions of investment in the logistics industry, logistics information technology, and agricultural financial input. The study suggests that enhancing investments in logistics industry and logistics information technology leads to an accelerated development in the agricultural product logistics sector, ultimately promoting coordination between the agricultural economy and agricultural product logistics. Moreover, lowering agricultural financial input can lead to more rational allocation and utilization of resources, hence further advancing the coordinated growth of agriculture and agricultural product logistics.

Keywords: agriculture; agricultural product logistics; system dynamics; policy simulation

1. Introduction

Agricultural product logistics serves agriculture, and agriculture cannot achieve high-quality development without efficient and convenient agricultural product logistic[1]. Agricultural product logistics and agriculture have a mutual influence on each other. In order to give full play to the role of agriculture in promoting agricultural logistics and agricultural product logistics in promoting agricultural economic growth, it is necessary to formulate scientific and effective coordinated development policies of agriculture and agricultural logistics.

Sichuan Province, situated in the upper reaches of the Yangtze River, boasts rich agricultural resources and a well-developed economy and transport system. The agricultural and logistics industries in Sichuan Province have flourished since the reform and opening up, and it is of great practical significance to study the coordinated development policy of agriculture and agricultural product logistics. This study uses the statistical data of Sichuan Province from 2009 to 2021, and uses Vensim PLE software to establish the dynamic model of agriculture and agricultural product logistics system in Sichuan Province, and puts forward scientific policy suggestions through the system simulation.

2. System analysis

Agriculture and agricultural product logistics industry promote each other, agriculture is the foundation and premise, agricultural products logistics is the development and guarantee[2]. Agricultural product logistics is a distinct component of the logistics industry and its connection with agriculture in the agricultural product logistics market is seen as a transactional relationship that is influenced by the laws of supply and demand[3]. Taking into account the input-output process of the agriculture and logistics industry in Sichuan Province, the supply and demand dynamics within the agricultural logistics market and data availability, the primary variables of the system have been identified, and the causal relationship between agriculture and agricultural product logistics system was drawn with Vensim PLE software as shown in Figure 1.
Fig. 1 Causal relationship diagram of agriculture and agricultural logistics system in Sichuan Province

The arrows in Figure 1 indicate the causality between the variables, and the positive and negative signs indicate the direction of the relationship. The main feedback loops in Figure 1 are as follows:

(1) Gross agricultural product of Sichuan → + Financial inputs to agriculture in Sichuan Province → + Demand for agricultural product logistics → + Imbalance in agricultural product logistics → - GDP of Sichuan Province → + Gross agricultural product of Sichuan. This negative feedback loop reflects that the development of the agricultural economy promotes the logistics demand for agricultural products and exacerbates the imbalance in agricultural logistics, which is unfavourable to the development of the agricultural economy.

(2) GDP of Sichuan Province → + Sichuan Logistics industry investment → + Agricultural logistics supply → - Imbalance in agricultural product logistics → - GDP of Sichuan Province. This positive feedback loop reflects that economic development drives the investment in logistics industry and slows down the imbalance in agricultural logistics, thus promoting economic development.

(3) GDP of Sichuan Province → + Sichuan logistics information technology investment → + Agricultural logistics supply → - Imbalance in agricultural product logistics → - GDP of Sichuan Province. The loop is similar to loop (2), highlighting the importance of IT investment.

3. Model construction

System Dynamics is a computer simulation approach used to analyze the dynamic behaviour of socio-economic systems\(^4\), which has a strong applicability in studying the coordinated development of agriculture and agricultural products logistics. According to Figure 1 and simulation needs, referring to the relevant research results\(^5\), the model flow diagram is designed as shown in Figure 2.
Fig. 2 Model flow diagram of agriculture and agricultural product logistics system in Sichuan Province

Figure 2 has a total of 24 variables including 2 state variables, 4 rate variables and 18 auxiliary variables as shown in Table 1.

Table 1 Main variables and descriptions

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Variable name</th>
<th>Variable description</th>
</tr>
</thead>
<tbody>
<tr>
<td>State variables</td>
<td>Gross agricultural product of Sichuan</td>
<td>It represents the development level of Sichuan's agriculture, expressed as the total output value of agriculture, forestry, animal husbandry and fishery.</td>
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<tr>
<td></td>
<td>Agricultural logistics supply</td>
<td>It represents the development level of Sichuan's logistics industry, expressed in terms of the total amount of agricultural logistics.</td>
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<tr>
<td>Rate variables</td>
<td>Increase in gross agricultural product</td>
<td>Increase in agricultural output compared to the previous year</td>
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<tr>
<td></td>
<td>Decrease in gross agricultural product</td>
<td>Decrease in agricultural output value compared to the previous year</td>
</tr>
<tr>
<td></td>
<td>Increase in supply</td>
<td>Increase in logistics supply due to increase in logistics-related investment</td>
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<tr>
<td></td>
<td>Decrease in supply</td>
<td>Depletion of logistics supply due to depreciation of fixed assets, etc.</td>
</tr>
<tr>
<td>Auxiliary variables</td>
<td>Growth rate of gross agricultural product</td>
<td>Growth rate of gross agricultural product compared to the previous year, expressed as a table function</td>
</tr>
<tr>
<td></td>
<td>Demand for agricultural logistics</td>
<td>Demand for agricultural logistics due to agricultural economic development and inputs</td>
</tr>
<tr>
<td></td>
<td>GDP of Sichuan province</td>
<td>The economic development of Sichuan Province</td>
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<td></td>
<td>Logistics industry investment</td>
<td>Industry investment in fixed assets in transportation, warehousing and postal industry</td>
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<tr>
<td></td>
<td>Investment in logistics information technology</td>
<td>Investment in information transmission, software and information technology service industry</td>
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<td></td>
<td>Agricultural financial input</td>
<td>Expressed as the input of local public finance in agriculture, forestry and water affairs.</td>
</tr>
<tr>
<td></td>
<td>Effective coefficient of Logistics industry investment</td>
<td>Degree to which investment in logistics industry is transformed into agricultural logistics supply after investment</td>
</tr>
<tr>
<td></td>
<td>Effective coefficient of investment in information technology</td>
<td>Degree to which investment in information technology is transformed into agricultural logistics supply after investment</td>
</tr>
<tr>
<td></td>
<td>Delayed investment in logistics industry</td>
<td>The lagging effect of investment in logistics industry on the growth of agricultural logistics supply</td>
</tr>
</tbody>
</table>
4. Variable equation

The data of this paper comes from the statistical data published by the government, such as Sichuan Provincial Statistical Yearbook and Sichuan Provincial Logistics Industry Operation Bulletin. The relevant statistical data of Sichuan province from 2009 to 2021 are used to establish the kinetic equations of variables, and the formula, assignment, dimension and description of each variable are as follows:

(1) Gross agricultural product of Sichuan = INTEG (Increase in gross agricultural product - decrease in gross agricultural product, 3689.81), 3689.81 is the initial value for the gross output of agriculture, forestry, livestock, and fisheries in 2009, the unit is 100 million yuan.

(2) Increase in gross agricultural product = Growth rate of gross agricultural product (GAP) x Gross agricultural product (GAP) of Sichuan province, the unit is 100 million yuan.

(3) Growth rate of gross agricultural product = WITHLOOKUP(Time, (2009, 0)-(2021, 1), (2009, 0.106238), (2010, 0.208467), (2011, 0.101444), (2012, 0.0344451), (2013, 0.047652), (2014, 0.0831776), (2015, 0.0688435), (2016, 0.0203367), (2017, 0.0345189), (2018, 0.0964056), (2019, 0.168208), (2020, 0.0181111), (2021, 0.0125)), expressed by a table function in Dmnl (dimensionless).

(4) Decrease in gross agricultural product = Increase in gross agricultural product x supply-demand imbalance impact factor x ABS (Logistics supply-demand ratio - 1). The unit is 100 million yuan.

(5) Agricultural logistics supply = INTEG (supply added value - supply decreased value, 3689.8). In order to obtain better simulation effect, the total amount of agricultural logistics is expressed here by the total amount of agricultural logistics, which is convenient to realize the same magnitude of logistics system and agricultural system. 3689.8 is the initial value, and the initial value takes the total amount of agricultural products logistics in 2009, and the unit is 100 million yuan.

(6) Increase in supply = Delayed investment in information technology x Effective coefficient of investment in information technology + Delayed investment in logistics assets x Effective coefficient of investment in logistics assets. The unit is 100 million yuan.

(7) The effective coefficient of logistics asset investment is 0.4 according to the calculation, and the unit is Dmnl.

(8) Effective coefficient of investment in information technology is 0.6 in Dmnl.

(9) Decrease in supply = Supply depletion factor x Agricultural logistics supply. The unit is 100 million yuan.
(10) GDP of Sichuan province = \(\text{WITHLOOKUP(Time,\{(2009,0)-(2021,10)\},(2009,1415.3),(2010,1722.4),(2011,21050.9),(2012,23922.4),(2013,26518),(2014,28891.3),(2015,30342),(2016,33138.5),(2017,37905.1),(2018,42902.1),(2019,46363.8),(2020,48501.6),(2021,53850.8)\})\), is expressed by a table function in Dmnl.

(11) Investment in logistics assets = GDP of Sichuan province × Logistics industry investment ratio/Logistics supply-demand ratio. The unit is 100 million yuan.

(12) Investment in logistics information technology = GDP of Sichuan province × Logistics information technology investment ratio/Logistics supply-demand ratio. The unit is 100 million yuan.

(13) Agricultural financial input = Agricultural financial investment ratio × Gross agricultural product of Sichuan × Logistics supply-demand ratio. The unit is 100 million yuan.

(14) Agricultural financial investment ratio = \(\text{WITHLOOKUP(Time,\{(2009,0)-(2021,10)\},(2009,0.142),(2010,0.1227),(2011,0.0568),(2012,0.0852),(2013,0.1187),(2014,0.1277),(2015,0.157),(2016,0.1915),(2017,0.2251),(2018,0.2365),(2019,0.2244),(2020,0.2597),(2021,0.3058)\})\), is expressed by a table function in Dmnl.

(15) Delayed investment in logistics assets = \(\text{DELAYFIXED(Investment in logistics,1,1200)}\). The delay of logistics asset investment belongs to material delay. It is considered that there is one year delay, the initial value of the delay is 1200, and the unit is 100 million yuan.

(16) Delayed investment in information technology = \(\text{DELAYFIXED(Investment in logistics information technology,1,130)}\), which belongs to material delay. It is considered that there is one year delay, the initial value of the delay is 130, and the unit is 100 million yuan.

(17) Delayed financial investment in agriculture = \(\text{DELAYFIXED(Agricultural financial input,1,300)}\), which belongs to material delay. It is considered that there is a one year delay, the initial delay value is 300, and the unit is 100 million yuan.

(18) Demand for agricultural logistics = Delayed financial investment in agriculture × Demand coefficient of agricultural product logistics + 3861.27, through SPSS of agricultural product logistics demand, agricultural financial input regression analysis, the unit is 100 million yuan.

(19) Logistics supply-demand ratio = agricultural logistics supply / logistics demand of agricultural products, the unit is Dmnl.

(20) Logistics demand coefficient of agricultural products, take the regression coefficient of 2.186, the unit is Dmnl.

(21) The logistics information technology investment ratio which is considered as the average value of the logistics information technology investment ratio from 2009 to 2021, is 0.00745, the unit is Dmnl.

(22) Logistics asset investment ratio, taking the average value in 2009-2021, is 0.1126, and the unit is Dmnl.

(23) Supply depletion factor, which has been verified in several model simulations, is taken to be 0.25 in Dmnl.

(24) Supply-demand imbalance impact factor, which has been tested in several model simulations, is taken to be 0.3 in Dmnl.

5. Model testing and policy simulation

5.1 Model testing

The total agricultural GDP and logistics demand of agricultural products are selected as comparative indexes, and the simulation data are obtained from the simulation model; the relative errors of indexes calculated with the simulation data and statistical data are shown in Table 2.

<table>
<thead>
<tr>
<th>Time (year)</th>
<th>Gross Agricultural Product of Sichuan (billions of yuan)</th>
<th>Demand for Agricultural Logistics</th>
<th>Relative error of agricultural GDP in Sichuan (%)</th>
<th>Relative error of demand for agricultural logistics (%)</th>
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Table 2 Model test results
As can be seen from Table 2 and Table, the relative errors of agricultural GDP and agricultural logistics demand in Sichuan province are within 10%, which can be judged that the model fit is good to meet the simulation needs.

5.2 Policy simulation

There are three variables that directly affect the demand of agricultural products and the supply of agricultural products logistics in Sichuan Province, namely, the logistics industry investment ratio, the logistics information technology investment ratio and the agricultural financial investment ratio[6], which are selected as policy regulation variables. Assuming that other variables in the model remain unchanged, changing the value of policy regulation variables is used to indicate policy adjustment. The following is the policy simulation and analysis from the logistics industry investment, logistics information technology investment and agricultural financial input.

(1) Logistics industry investment policy. The logistics industry investment ratio is increased from the original 0.1126 to 0.15 and 0.30, and the values of other variables remain unchanged. After running the model, the gross agricultural product of Sichuan and agricultural logistics supply and demand ratio data are shown in figures 3.1 and 3.2.
Figure 3.1 Logistics industry investment policy simulation: logistics supply-demand ratio

As depicted in figure 3.1, an augmented investment proportion in logistics assets to 0.15 results in an increase in agricultural logistics supply, leading to a rise in the supply-to-demand ratio and almost reaching an equilibrium state. Subsequently, with a further increase in investment proportion to 0.3, the supply surpasses the demand, thereby causing a state of supply-demand imbalance. As depicted in Figure 3.2, an increase in the proportion of investment in logistics assets to 0.15 leads to a 0.76 per cent increase in agricultural GDP, while a further increase to 0.3 results in a decrease of 1.07 per cent. A modest upsurge in logistics investments evidently regulates the balance between agricultural supply and demand. However, an excessive investment would lead to resource wastage.

⑵ Logistics information technology investment policy. The logistics information technology investment ratio is increased from the original 0.00745 to 0.03 and 0.05, while keeping the value of other variables constant. The simulation outcomes are depicted in figures 4.1 and 4.2.
As demonstrated in figures 4.1 and 4.2, when the investment ratio in logistics information technology rises to 0.03, there is an improvement in the supply of agricultural logistics, an increase in the supply and demand ratio, and a 0.74% increase in the average gross agricultural product of Sichuan Province. When the investment ratio in logistics information technology reaches 0.05, there is a continued improvement in the supply of agricultural logistics which leads to greater balance in the supply and demand of agricultural products. This, in turn, results in an increase in the value of agricultural production in Sichuan Province compared to the initial state. However, the growth is not significant, with an average increase of only 0.46%, and the supply is slightly larger than the demand.

(3) Agricultural financial input policy. The agricultural financial input ratio is reduced by 30%, and the values of other variables remain unchanged. The simulation results of the operation model are illustrated in figure 5.1 and 5.2.
Figure 5.2 Agricultural financial input policy simulation: the gross agricultural product of Sichuan

As depicted in figures 5.1 and 5.2, after the 30 per cent reduction in agricultural financial inputs, logistics supply and demand tend to be balanced, leading to an average increase of 0.78% in the gross agricultural product. This reduction not only conserves resources, but also enhances the overall coordination of supply and demand in the agricultural product logistics, subsequently promoting the development of the agricultural economy. This outcome has a significant impact on the advancement of high-quality, high-yield modern agricultural production in Sichuan Province.

Further analysis shows that if the agricultural financial input ratio were to be reduced by 20 percent, while at the same time the logistics industry investment ratio were to be increased to 0.13 and the logistics information technology investment ratio were to be increased to 0.015, the ratio of supply-demand would reach equilibrium, the gross agricultural product would be increased by an average of 0.85 percent, and the economical system would achieve coordinated development.

6. Summary

By establishing the dynamic model of agricultural and agricultural products logistics system, the following conclusions are obtained:

(1) There are mutual promotion and restriction between agricultural economy and agricultural logistics industry, and the two have strong coupling. When agricultural products logistics demand and logistics supply match, agriculture and agricultural products logistics achieve coordinated development.

(2) Different financial input policies will have different degrees of impact on the balance of supply and demand. Increasing the investment in logistics industry, logistics information technology or reducing agricultural financial input can slow down the incoordination between agricultural economy and agricultural logistics to a certain extent and promote the development of agricultural economy.

(3) Excessive investment in the logistics industry will aggravate the incoordination between supply and demand, and hinder the development of agricultural economy.

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Reference


