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Research on Chongqing Logistics Industry and Economic Development Policy Based on System Dynamics

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Abstract: In this paper, the system dynamics model of Chongqing logistics industry and economy is established to explore the interaction mechanism between Chongqing logistics industry and economy, and the data are selected from Chongqing Statistical Yearbook to simulate the logistics fixed asset investment and education investment policy. The results show that the logistics industry policy has obviously promoting effect on economic growth and logistics efficiency. Increasing the investment of logistics fixed assets and education will help to promote the balance of logistics supply and demand in Chongqing city.

1. Introduction

As a largest economic center city and the important transportation hub in southwest China and the upper reaches of Yangtze River, Chongqing city urgently needs improving the logistics management system and coordination mechanism to accelerate the development of modern logistics industry. As for the logistics coordination mechanism, the coordination relationship between logistics and economy is very significant, and researchers attach great importance to it. Relevant studies mainly focus on revealing the coordinated development relationship between logistics and economy with empirical methods, and propose that the two have positive correlation [1-3], different coupling coordination degree levels [4-7] and influencing factors [8-10]. A few scholars analyzed the relationship and policies by building a system dynamics model [11-12].

The existing research results reveal the coordinated development relationship between logistics and economy,but the quantitative policy research is weak, while ignoring some important factors including import and export trade, residents' consumption level and logistics education. Based on the existing literature, the Chongqing logistics industry and economic development policy model is built by the system dynamics theory to simulate the Chongqing logistics industry policy and give some suggestions.

2. The analysis of Chongqing logistics industry and economic system

2.1 System boundaries

The impact of the logistics industry on the economy is mainly existed in the aspects of consumption, import and export, and logistics services, while the economy influences the development of the logistics industry from the aspects of logistics demand and supply. The reciprocal influence mechanism of the logistics industry and economy is mainly realized through the demand and supply of the logistics market. The purpose of this modeling is to conduct policy simulation and put forward policy suggestions from consumption, import and export and education investment. According to the modeling purpose, logistics and economic action mechanism and policy simulation need, the following 13 variables are determined as the system boundary of the model as be shown in Table 1.

Logistics quantity in Table 1 is expressed in cargo turnover, including the actual logistics quantity, logistics demand, logistics supply, supply and demand balance in the logistics market and so on.

Table 1. Chongqing logistics industry and economic system boundary

Influence factor	Variable
Economic development	logistics output value, actual logistics quantity, logistics demand, logistics supply, logistics market balance between supply and demand
Logistics supply	educational investment, logistics practitioners, logistics talents, logistics fixed assets investment, fixed assets investment
Logistics demand	GDP, consumption level of residents, total imports and exports

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2.2 Analysis of causality

Considering comprehensively the consumption, import and export, education investment, logistics demand and supply mechanism, the variables in Table 1 are correlated to obtain the causal relationship diagram between Chongqing logistics industry and economic development as showed in Figure 1.

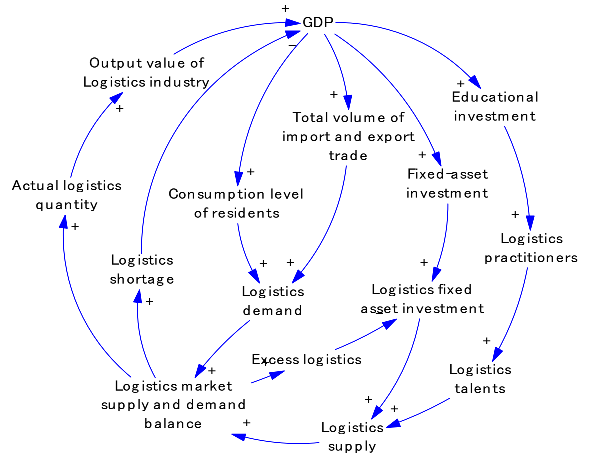

Figure 1 Causal relationship between logistics industry and economic development of Chongqing city

In Figure 1, the arrow line represents the causal relationship between two variables, and the positive and negative signs beside the arrow line represent the direction of correlation. The arrow line and the two connected variables form a causal chain, and the connected causal chain constitutes a feedback loop.

There are complex nonlinear relationships between variables, which constitute seven causal feedback loops including①GDP→+educational investment→+ logistics practitioners→+ logistics talents→+ logistics supply→+ logistics market supply and demand balance →+ actual logistics quantity→+ logistics industry output value →+GDP.

②GDP→+fixed asset investment→+logistics fixed asset investment→+logistics supply→+logistics market supply and demand balance→+actual logistics →+logistics quantity industry output value→+GDP.

③GDP→+total import and export volume→+logistics demand→+logistics market supply and demand balance→+actual logistics quantity→+logistics output value→+GDP.

④GDP→+consumption level of residents→+logistics demand→+logistics market supply and demand balance→+actual logistic quantity→+logistics output value→+GDP.

⑤GDP→+total import and export volume→+logistics demand→+logistics market supply and demand balance→+logistics shortage→-GDP.

⑥GDP→+consumption level of residents→+logistics demand→+logistics market supply and demand balance→+logistics shortage→-GDP.

⑦logistics fixed asset investment→+logistics supply→+logistics market supply and demand balance→+excess logistics→-logistics fixed asset investment. The first, second, third and fourth loops are positive feedback loops where the change of the starting variable causes the subsequent variable to be changed in the same direction and finally enhances the original change. The fifth, sixth and seventh loops are negative feedback loops where the negative sign in the loops is odd, The change of the starting variable will cause the increase or decrease of subsequent variables and finally inhibit the original change of the starting variable.

3. Construction of dynamics model of Chongqing logistics Industry and economic system

3.1 Model flow diagrams

According to Figure 1 and the requirements of policy simulation, the dynamic model flow diagram for Chongqing logistics industry and economic system is established by dynamics software Vensim PLE as showed in Figure 2.

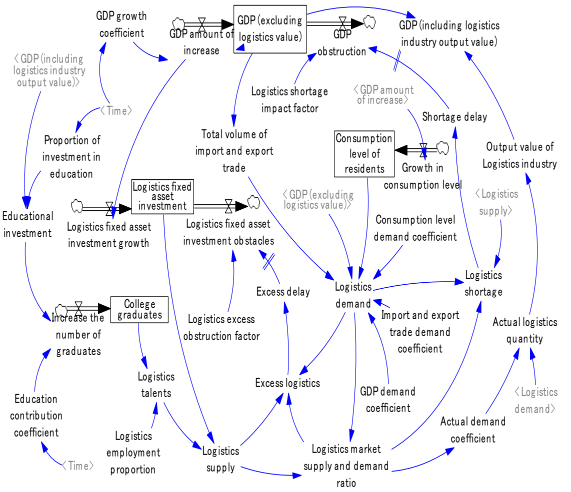

Figure 2 Chongqing logistics industry and economic system flow map

In figure 2, the variables in the box are level variable, and the increment beside the rate symbol is rate variable. The rests are auxiliary variables and constants.

3.2 Parameter estimation and variable equation

3.2.1 Parameter estimation

Initial values of four state variables in the model are from statistical data of Chongqing Statistical Yearbook in 2007 as showed in Table 2 below.

Table 2 Initial value of the status variables

Variable	Initial value	Unit
GDP (excluding logistics value)	3862.16	100 million
College graduates	11.27	ten thousand persons
Logistics fixed asset investment	280.77	100 million

Consumption level of residents	1403.58	100 million

According to relevant data, the proportion of logistics employment of graduates in Chongqing is 0.03.

3.2.2 Variable equation

The main variables and equations of the model are shown in Table 3.

Table 3 Main variables and equations

Variable	Equation	Unit
GDP (excluding logistics value)	INTEG(GDP amount of increase-GDP obstruction, 3862.16)	100 million
GDP amount of increase	GDP (excluding logistics industry output value) * GDP growth coefficient	100 million
GDP obstruction	Logistics shortage delay * Logistics shortage impact factor	100 million
GDP (including logistics industry output value)	GDP (excluding Logistics industry output value) + Logistics industry output value	100 million
Logistics shortage impact factor	0.0031	Dmnl
Total volume of import and export trade	Import and export trade table function	100 million
Consumption level of residents	INTEG(Growth in consumption level，1403.58)	100 million
Logistics demand	761.06+0.149*GDP (excluding logistics value)-0.028* Total volume of import and export trade-0.02*Consumption level of residents	Hundred million tonnage kilometers
Logistics supply	EXP(5.841)*(Logistics talent^(-1.036))*(Logistics fixed asset investment^0.873)	Hundred million tonnage kilometers
Logistics fixed asset investment	INTEG(Logistics fixed asset investment growth-Logistics fixed asset investment obstacles,280.77)	100 million
Logistics fixed asset investment obstacles	Logistics excess delay * Logistics excess obstacle factor	100 million
Logistics excess obstruction factor	0.0035	Dmnl
Educational investment	GDP (including logistics industry output value)*Proportion of investment in education	100 million
College graduates	INTEG(Increase the number of graduates，11.27)	Ten thousand persons
Increase the number of graduates	Education input * Education contribution coefficient	Ten thousand persons
Logistics talent	College graduates * Graduates logistics employment proportion	Ten thousand persons
Logistics market supply and demand ratio	Logistics supply / Logistics demand	Dmnl
Logistics shortage	IF THEN ELSE(Logistics market supply and demand ratio>=1,0,Logistics supply-Logistics demand)	Hundred million tonnage kilometers
Shortage delay	DELAY FIXED(Logistics shortage,1,0)	Hundred million tonnage kilometers
Excess logistics	IF THEN ELSE(Logistics market supply and demand ratio>1,Logistics supply-Logistics demand,0)	Hundred million tonnage kilometers
Excess delay	DELAY FIXED(Excess logistics,1,0)	Hundred million tonnage kilometers
Actual demand coefficient	IF THEN ELSE(Logistics market supply and demand ratio>1,1,Logistics market supply and demand ratio)	Dmnl
Actual logistics quantity	Logistics demand * Actual demand coefficient	Hundred million tonnage kilometers
Output value of Logistics industry	0.253*Actual traffic+10.17	100 million

In Table 3, INTEG represents the integral, DELAY FIXED is a delay function, parameter 1 represents a delay of 1 year, EXP is an exponential function, and IF THEN ELSE is a conditional function.

It is difficult to assess the quantitative relationship between variables. The table function and multiple regression analysis are utilized in this model.

1)Table functions

Table functions define the nonlinear relationship between two variables in a graphical form, which is an important feature of the system dynamics model. Vensim table function format is that: dependent variable =WITHLOOKUP (independent variable); Look up=([(minimum value of independent variable, minimum value of dependent variable)-(maximum value of independent variable, maximum value of dependent variable)],(corresponding point sets of independent variable,dependent variable).

The growth coefficient and logistics fixed asset investment growth scale function is established by using the statistical data to calculate the corresponding point sets.

(1) Growth coefficient.

The growth coefficient is the proportion of the GDP added value of the current year to the GDP of the previous year. Its table function for Time is as following:

GDP growth coefficient=WITHLOOKUP(Time);Look up=([(2006,0)-(2021,0.9)],(2006,0.233),(2007,0.233),(2008,0.127),(2009,0.215),(2010,0.265),(2011,0.149),(2012,0.125),(2013,0.126),(2014,0.098),(2015,0.126),(2016,0.116),(2017,0.075),(2018,0.094),(2019,0.063),(2020,0.063)).

Similarly, the table function of the proportion of education input and the total volume of import and export trade can be achieved.

(2) Growth of logistics fixed asset investment.

Its table function for GDP growth is as follows:

Logistics fixed asset investment growth=WITHLOOKUP (GDP growth); Look up=([(600,-100)-(3600,500)],(84872.73),(1046.62,105.59,.35),(702.32,231.4),(1341.7,100.89),(2004.77,42.38),(1423.19,221.1),(1380.85,295.76),(1557.92,85.84),(1371.52,302.83),(1931.46,264.34),(1992.43,-48.78),(1451.1,218.92),(1939.21,121.72),(1421.29,344.28),(1458.07,168.48)).

Similarly, the scale function of the growth of residents' consumption level can be achieved.

2)Multiple regression analysis

(1)Logistics demand.

Multiple linear regression analysis is used to determine the regression equation between logistics demand and total import and export trade, GDP and total social consumption. Relevant statistical data were input into SPSS for fitting analysis, and the result was: R2=0.956, and $P < 0.05$, indicating a good fit of the model. So,Logistics demand =761.06+0.149*GDP (excluding logistics output value)-0.028*Total import and export trade-0.02*household consumption level.

(2)Logistics supply.

The basic factors of production in the logistics industry are labor and capital. The labor force is represented by logistics talents, and the capital is represented by logistics fixed assets. The Cobb-Douglas production function fitting analysis based on relevant data can be obtained as follows:The determination coefficient R^2= 0.924 indicates that the model has a good degree of fit, F=86.237, P<0.05 indicates that the regression model passes the F test.

So, Logistics supply=EXP(5.841)*(Logistics talents ^(-1.036))*(Logistics fixed asset investment^0.873).

4.Model Test and Simulation

The model simulation time is set at years, simulation step to 1 year, initial TIME =2006, and final TIME=2020, or simulation period from 2006-2020.

4.1 Model Test

Viewing from outside the model, this model includes all the variables of the causal diagram and seven feedback loops. In order to analyze the feedback characteristics, the simulation data of the main variables in Table 1 was obtained by the operation model, and it was found that the changes of the simulation data correctly reflected the characteristics of the seven feedback loops. It can be seen that the model correctly describe the variable relationship and the mechanism of systemic action, and the model boundary meets the needs of policy simulation.

GDP (including the output value of logistics industry) and investment in fixed assets of logistics were selected as comparison indicators, and corresponding simulation data were obtained by running the model as showed in Table 4.

Table 4 Comparison of the simulated values and the real values

Time	GDP (including logistics industry output value)			Logistics fixed asset investment		
	Actual value	Analog value	Error rate	Actual value	Analog value	Error rate
2006	3900.26	3877.64	-0.58%	280.77	280.77	0.00%
2007	4770.72	4775.1	0.09%	353.497	353.5	0.00%
2008	5899.49	5871.51	-0.47%	458.847	458.85	0.00%
2009	6651.22	6673.68	0.34%	690.247	690.07	-0.03%
2010	8065.26	8048.68	-0.21%	791.13	795.23	0.52%
2011	10161.17	10164	0.03%	833.51	837.61	0.49%
2012	11595.37	11626.9	0.27%	1054.61	1058.59	0.38%
2013	13027.6	13057.1	0.23%	1350.37	1355.11	0.35%
2014	14623.78	14678.2	0.37%	1436.21	1441.41	0.36%
2015	16040.54	16109	0.43%	1739.05	1743.61	0.26%
2016	18023.04	18086.8	0.35%	2003.39	1996.06	-0.37%
2017	20066.29	20052.7	-0.07%	1954.61	1963.06	0.43%
2018	21588.8	21544.7	-0.20%	2173.52	2181.15	0.35%
2019	23605.77	23491.1	-0.49%	2295.24	2299.13	0.17%
2020	25002.79	24973.3	-0.12%	2639.52	2581.87	-2.18%

As can be seen from Table 4, the relative error of the simulation is below ±10%, the simulation results of the model reflect the dynamics of the logistics industry and economic development in Chongqing city, so the model can be used for policy experiments.

4.2 Policy simulation

After running the model, it can be observed in the simulation results that both the supply and demand of logistics are on the rise, and the problem of logistics shortage is prominent. Therefore, the logistics fixed assets investment and education investment are chosen for policy simulation.

(1) The logistics fixed asset investment policy. Increasing the growth of logistics fixed asset investment by 50% since 2006, the simulation results are shown in Figure 3.

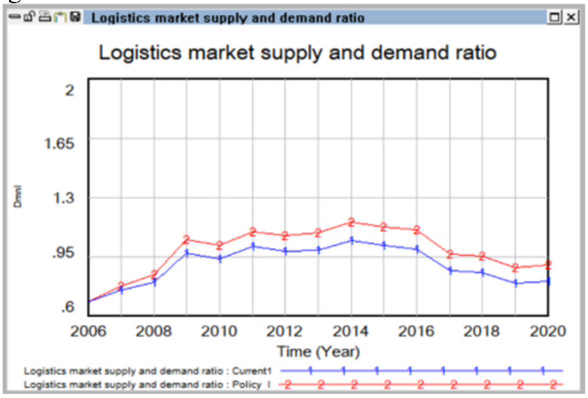

Figure 3 Investment policy simulation

As can be seen from Figure 3, although the ratio of supply and demand is closer to 1 after the policy adjustment, and tends to balance between supply and demand, logistics supply is still smaller than the logistics demand after 2017.

(2) The educational input policy.

Increasing the proportion of educational investment by 0.005 per year since 2006, the simulation results are presented in Figure 4.

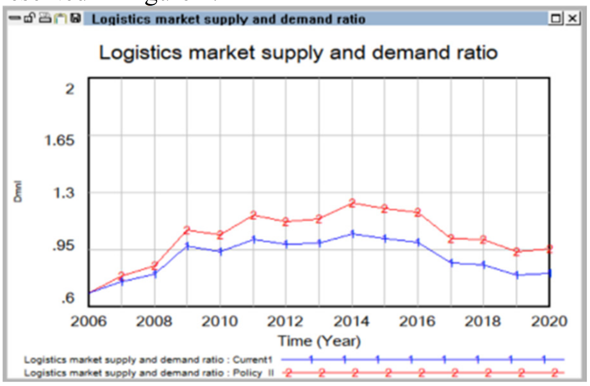

Figure 4. Educational policy simulation

As can be seen from Figure 4, increasing educational input can promote the supply, but it still does not reach the balance between supply and demand.

In view of this, we should continue to increase investment in logistics fixed assets and education, strengthen the construction of logistics infrastructure, input more logistics talents for the logistics industry, and improve logistics efficiency until supply and demand balance.

5.Conclusion

The logistics market in Chongqing city is near the balance of supply and demand, but there is a shortage of logistics, and it is urgent to adjust the future development policy. In order to solve the problem of logistics shortage, the investment of logistics fixed assets should be increased appropriately, the construction of logistics infrastructure should be strengthened, and a scientific logistics personnel training system should be established.

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