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The Impact of Logistics Development on Economic Growth for Shanxi Province in China: Empirical Evidence Based on System Dynamics

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ABSTRACT

Based on the system dynamics theory, the system dynamics model is constructed by using the relevant economic and logistics data of Shanxi Province from 2015 to 2020. By changing the economic barrier factor, logistics demand conversion factor and logistics supply capacity factor, the empirical simulation is conducted with Vensim software. The correlation between economy and logistics development in Shanxi Province is simulated under different scenarios. The research conclusion shows that improving logistics supply capacity will have a significant positive impact on economic development. The same is true of the solid implementation of supply-side structural reform. The logistics backlog caused by the difficulty of logistics supply capacity to meet the logistics demand will have a significant negative impact on economic development. It has certain guiding significance for the study of economic growth and logistics development in Shanxi Province.

KEYWORDS: Logistics development; Economic growth; System dynamics; Simulation

1. INTRODUCTION AND LITERATURE REVIEW

In today's society, logistics is the foundation of national economy. At the same time, logistics has become a new engine to promote the healthy and stable development of the economy. With the continuous optimization of industrial structure and the gradual deepening of economic transformation, the process of logistics specialization and socialization has accelerated obviously. It has stimulated the growth of logistics demand in various industries and improved the demand level of logistics. Ruan, Liang, and Huang (2021) pointed out that the logistics industry is closely related to the national economy and is of great significance to the sustainable economic development [1]. There are many factors affecting the development of logistics, and the reasons are complicated. In different fields, many domestic scholars have studied the impact of logistics industry development on economic growth from multiple perspectives. Zhang (2020) used four groups of panel data in 1997, and analyzed the relationship between logistics development and economic growth in various regions of China [2]. Li and Majid (2021) analyzed the growth of green logistics performance and its impact on the environment in a number of countries during 2007-2019[3]. Li and Li (2022) used the theory of combining industrial analysis and regional analysis to analyze the internal factors of logistics system and economic development system. They points out the positive role of logistics industry in economic development [4]. Production logistics systems are usually affected by high operational dynamics. According to R.J. (2014), the development of e-commerce is the reason for the development of logistics and the growth of economic GDP in China, but the growth of economic GDP is not the reason for the development of e-commerce and logistics in the long run [5] . Qu and Wang (2017) applied system dynamics to design the structure of a statistically robust system to accommodate common

dynamics [6]. By applying the basic principles of system dynamics, Dai and Li (2017) analyzed the disadvantages of the development of logistics industry in Shanxi Province and Beijing respectively, and put forward effective guiding suggestions, deepening understanding of the essence of the regional logistics system [7]. Tian and Yang (2019) studied the effective operation of the logistics system in Shanxi Province [8]. They found that it depended not only on their own basic conditions and external economic development, but also on the degree of coordination between the internal influencing factors [8]. Zou (2018) analyzed the inseparable relationship between modern logistics and economic growth in the e-commerce development environment [9]. Sun (2022) studied the relationship between logistics and regional economy from the aspect of land transportation [10]. He put forward the strategy of coordinated development, which increased the attention of the region to the logistics and transportation capacity. In the context of the Belt and Road, Xu (2021) analyzed the pillar role of the logistics industry and proposed the development direction of the logistics industry in the new situation [11]. Taking Yunnan Province as an example, Si and Li (2022) put forward suggestions on logistics and economic promotion for the development of South and Southeast Asia based on system dynamics [12]. Guizhou Province and this province are located in the central region, and the development of logistics industry is relatively slow. Li and Wang (2018) used the Logistic model to put forward corresponding development suggestions on the positive role of the logistics industry in Guizhou Province in regional economic growth [13]. Based on high-quality development, Pan (2022) pointed out the important role of logistics industry in economic growth and industrial optimization and upgrading in the short and long term [14]. Dong, Xu and Huang (2019) took Beijing as an example and attempted to analyze the quantitative relationship between ULS implementation strategy and urban transport logistics sustainability based on real world simulation using system dynamics (SD) method to solve this problem [15]. In the context of digital trade in the new era, Tao (2022) further proposed the logistics policy to achieve high-quality development in the context of digital trade by using the system dynamics method [16]. Kang and Wang (2021) found through the model that improving the supply capacity of logistics, scientific and technological innovation and technological progress can promote regional economic development and promote the development of regional logistics industry [17]. Wu and Kang (2017) found a positive interaction between the development of logistics industry and economic growth [18]. The rapid development of the logistics industry has greatly promoted economic growth. He, Wang, and Guo (2020) emphasized that attention should be paid to modern logistics while promoting urban economic growth [19]. Kong and Zhang took Zhengzhou City and Lanzhou City as examples for research [20].

Many practices show that this systematic analysis method has been widely used in the field of logistics and economic research. Therefore, under the current situation of logistics and economy in Shanxi Province, combined with the basic principles of system dynamics, further explore the impact of logistics development on economic growth. With this method, we can solve the problem of complex time-varying and multiple feedback loops. Through the simulation of the relationship between the logistics system and economic development in Shanxi Province, this paper puts forward feasible suggestions for the development of the logistics industry in Shanxi Province in the future.

2. SYSTEM DYNAMICS MODEL ESTABLISHMENT AND SIMULATION TEST

In 1956, Professor Jay W. Forrester pioneered the discipline of system dynamics at the Massachusetts Institute of Technology. System dynamics, which is based on systems theory, cybernetics and other theories, is a comprehensive discipline connecting social science and natural science and other fields. The system dynamics horizontally includes comprehensive intersection, practicality and other attributes, and its problem analysis and solution method is the unity of qualitative and quantitative analysis. System dynamics takes qualitative analysis as the guide and quantitative analysis as the support, and conducts simulation research under the help of computer simulation technology. According to the fitting data and other results, this method starts from the internal microstructure and mechanism of the system. Solutions to practical problems can be found by studying the relationship between the internal structure of the system and its dynamic behavior. The system dynamics is especially suitable for solving complex nonlinear systems

such as economy and ecology, and large-scale systems such as multiple feedbacks.

Systematic Causal Analysis

With the expansion of the logistics industry in Shanxi Province in recent years, the logistics industry has become a new economic growth point and pillar industry in Shanxi Province. Shanxi Province is a large province of energy, and the logistics industry is an important part of its economic system. Therefore, logistics is inevitably related to and interacts with infrastructure construction and social fixed asset investment.

According to the empirical analysis of system integrity and hierarchy, the relationship between logistics and economic development is obtained. Besides, the following causal relationship diagram of the relationship between logistics and economic development is established.

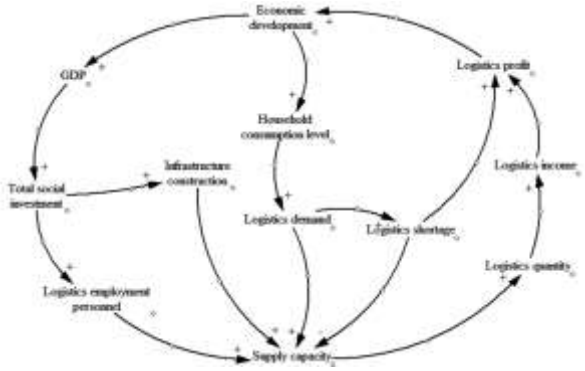

Figure 1: Causal Diagram of Relationship between Logistics and Economic Developmente

The causal relationship between logistics and economic development includes two basic feedback loops (see Figure 1). On the one hand, the increase of GDP will increase the consumption level of residents, which will promote economic development and stimulate the investment and demand of the logistics market. However, if the actual logistics supply capacity cannot meet the demand at this time, the logistics process will be blocked. In this case, there will be a serious shortage of logistics, hindering economic development. On the other hand, the growth of GDP will drive economic development. Economic development will not only drive the increase of investment in logistics assets, but also increase the government's investment in infrastructure construction and the training of logistics employees. These measures will effectively improve the supply capacity of logistics. Specifically, the logistics volume is increased. This will increase the income of the logistics industry, thereby promoting economic development.

Establishment of System Dynamics Model

Logistics is closely related to the level of economic development. The faster the logistics industry develops, the more it can promote the local economic development. On the contrary, the higher the level of economic development, the higher the requirements for the local logistics service system. Based on the principle of system dynamics, the model is built with VensimPLE software. Based on empirical causality analysis, the system dynamics model of logistics and economic development is established (see Figure 2).

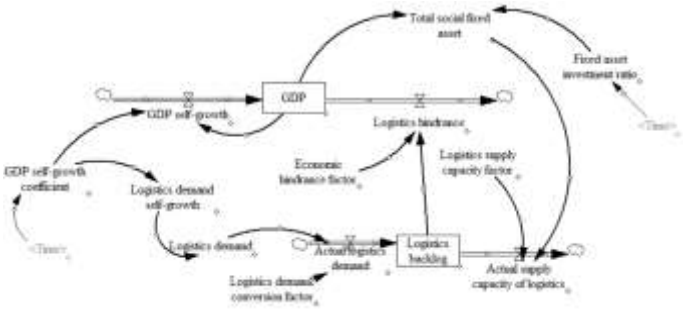

Figure 2: Systematic Flow Chart of Logistics and Economic Development

The state variable GDP is used to represent the economic development level of Shanxi Province (see Figure 2). The influence of various factors is considered through systematic thinking. Appropriate auxiliary variables are selected according to the actual situation. Among them, the logistics economic hindrance is used to represent the degree of hindrance of logistics industry development to the economy. It can be seen that it is mainly affected by economic barriers and logistics backlog. When the actual demand of logistics grows faster than the supply capacity of logistics, logistics backlog will occur, which will seriously hinder economic development.

System Dynamic Equation and Parameter Description

Based on empirical analysis of the system flowchart of economic development and logistics industry, the correlation between various variables in the model is determined. Its equations and parameters can be expressed by the following index data.

GDP=INTEG (growth amount of GDP - logistics obstructed amount of GDP, initial value)

Self-growth amount of GDP = GDP * self-growth coefficient of GDP

Logistics obstructed amount = logistics backlog * economic hindrance factor

Total social fixed asset investment = GDP * fixed asset investment ratio

Logistics backlog=INTEG (actual logistics demand - actual logistics supply capacity, initial value).

Actual logistics demand=logistics demand * conversion factor of logistics demand.

This paper uses the total social logistics to replace the actual logistics demand. This set of calculation system was developed by the China Federation of Logistics and Procurement, covering a comprehensive content.

Actual supply capacity of logistics = fixed asset investment of the whole society * logistics supply capacity factor

Self-growth coefficient of GDP =GDP self-growth coefficient table function.

GDP self-growth coefficient and table function.

The self-growth coefficient of GDP represents the ratio of the GDP added value of the current year to the growth of the previous year under natural conditions. Taking Shanxi Province as an example, this paper calculates the growth rate of GDP in the calendar years from 2015 to 2020 according to its GDP.

In recent years, the GDP growth rate of Shanxi Province has been between - 10% and 25%, presenting an overall upward trend. The real impediment of logistics to the economy will restrict the growth of GDP, so that the real GDP growth rate is slightly lower. The GDP growth coefficient is set as:

Self-growth coefficient of GDP = WITH LOOK UP (TIME, ([2015, 0)-(2020, 0.037)], (2015, 0), (2016, 0.009), (2017, 0.21), (2018, 0.1), (2019, 0.067), (2020, 0.037)).

The economic growth trend of Shanxi Province basically fluctuates around 0.1. It is in a relatively stable state after 2018.

Fixed asset investment coefficient. Fixed asset investment coefficient is the proportion of fixed asset investment of the whole society to the GDP of the province in that year. This study collects and sorts out relevant data of Shanxi Province from 2016 to 2020. It is assumed that GDP is an independent variable and the fixed asset investment coefficient is a dependent variable. Table function is established.

The growth rate of social fixed asset investment in Shanxi Province has been stable since 2016. The proportion will be close to 50% in 2020. As shown by data, the economic development of Shanxi Province is at a stage of steady growth. With the continuous expansion of investment scale in Shanxi Province, the investment structure of the province tends to be optimized. The proportion of fixed asset investment in the province has increased steadily.

Fixed asset investment coefficient=WITH LOOKUP (TIME, [(2009, 0) - (2020, 1)], (2016, 0.423), (2017, 0.424), (2018, 0.407), (2019, 0.417), (2020, 0.445)).

Determination of other parameter values

All selected indicators can be found in the statistical yearbook.

Simulation and Test

Firstly, the model is tested to ensure the stability, validity and authenticity of the model. System dynamics method is used to conduct modeling and simulation analysis of system development status. This paper selects the GDP for simulation to compare the error between the predicted value of simulation results and historical data in Shanxi Province.

Test of simulated stability

Through empirical analysis, this study changes the time step DT, and takes the value of changing the time step length as 3 months, 6 months and 1 year respectively to simulate and compare GDP. The error between simulated GDP and actual GDP is the smallest when the simulation step is 3 months. At this time, the model is the most stable. Therefore, the step length of three months is taken to predict GDP.

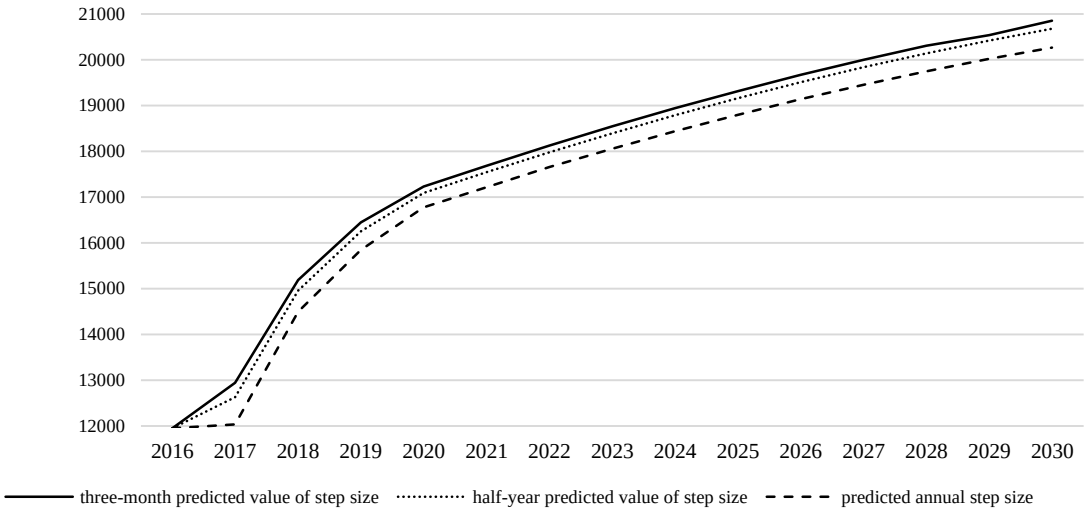

Figure 3: Stability Test of GDP Simulation

Parameter validity test

The actual GDP value of Shanxi Province from 2016 to 2020 is taken. The simulation results are compared with the existing data.

Table 1: GDP Simulation Effect Test

Year	Real GDP (in 100 million yuan)	GDP Simulation Value (in 100 million yuan)	GDP Error Value(%)
2016	11946.4	11946.4	0
2017	14484.3	12029.9	-16.95
2018	15958.1	14492.5	-9.18
2019	17026.7	15841.4	-6.69
2020	17651.9	16764.9	-5.02

It can be observed from the statistical data in Table 1 that the error is mostly controlled within 10%. It shows that the simulation effect of the model is in a good agreement with the actual situation and the accuracy of the model is high.

3. SIMULATION RESULTS

Based on the validity of the model, this study keeps other constant variables unchanged, changes the value of logistics supply capacity factor, economic hindrance factor and logistics actual demand conversion factor respectively, and compares and analyzes the changes of state variables under different conditions. Under different scenarios, the model parameters are set, as shown in Table 2.

Logistics shortage will hinder economic development. Therefore, the hindering effect of logistics on economy is reflected by the hindering factor of economic growth. According to the statistics of the economic impact of logistics in Shanxi Province in recent years, it is assumed to be 0.0015. According to the domestic economic environment, 80% of the logistics demand generated by the economic level is assumed to be converted into the actual demand. Namely, the value of logistics demand conversion factor is 0.8. Given that the level of logistics development in Shanxi Province is still at the initial stage, the current logistics supply capacity cannot be fully converted into the actual supply capacity. Therefore, the logistics supply capacity factor is assumed to be 0.7. Hence, the above data is taken as the initial value in Scheme 1.

Table 2: Simulation Parameters of Different Scenarios

Scenario Simulation		Economic Hindrance Factor	Logistics Demand Conversion Factor	Logistics Supply Capacity Factor
Level of Logistics obstruction	Scenario 1	0.0015	0.8	0.7
	Scenario 2	0.0025		
	Scenario 3	0.003		
Level of Logistics demand	Scenario 1	0.0015	0.8	0.7
	Scenario 4		1.0	
	Scenario 5		0.5	
Level of logistics supply	Scenario 4	0.0015	1.0	0.7
	Scenario 6			0.5
	Scenario 7			1.0

Data source: Author collation

Adjust the Factor of Economic Hindrance

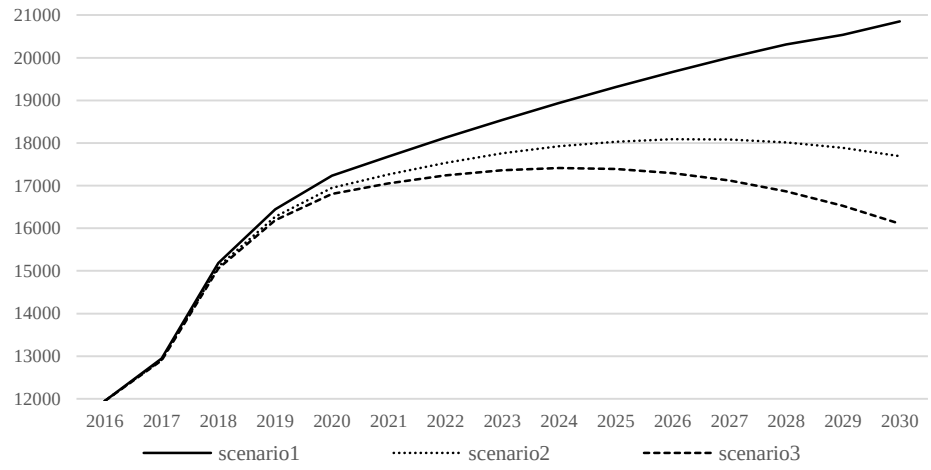

Figure 4: Simulation of the Impact of Different Economic Barriers on GDP

GDP is used to represent the level of economic development. By changing the economic hindrance factor, the change trend of GDP is analyzed. It is assumed that the economic hindrance factor of Option 1 is 0.0015, and the economic hindrance factors of Option 2 and Option 3 are 0.0025 and 0.003 respectively. The simulation results of different schemes are presented in Figure 4.

As shown in Figure 4, the error between the simulated GDP and the actual GDP in Scheme 1 is the smallest. Compared with the actual GDP, the simulated GDP of Scheme 2 and Scheme 3 has a large error. Therefore, the setting of correlation coefficient in Scheme 1 is more practical. The logistics industry will contribute more to the economic development if the hindrance of logistics to the economy is as small as possible. The GDP generated is also larger. Therefore, the economic hindrance factor is set as 0.0015.

Adjust the Factor of Logistics Demand Conversion

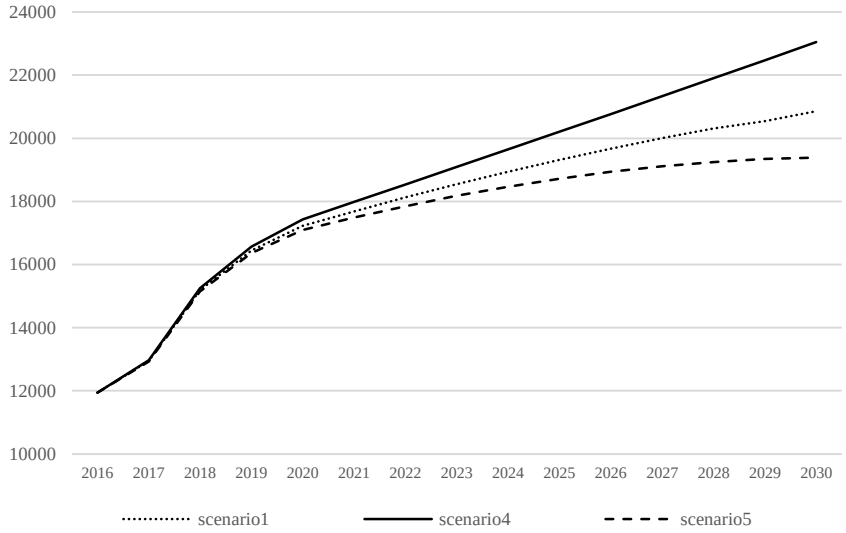

Figure 5: Influences of Different Logistics Demand Conversion Factors on GDP

It is assumed that other variables remain unchanged. Based on Scheme 1, this study changes the size of the logistics demand conversion factor. Changing the demand conversion factor of logistics means changing the proportion of economic development demand for logistics. It is assumed that the actual logistics demand conversion factors in Scheme 1, Scheme 4 and Scheme 5 are 0.8, 1.0 and 0.5 respectively. The results are presented in Figure 5. It can be observed from Figure 5 that when the logistics demand conversion factor is 1.0, GDP is the largest. When the logistics conversion factor is 0.5, GDP is the smallest. It can be seen that when the logistics demand is met as much as possible, the logistics industry will create greater economic value. Accordingly, the GDP generated is also the largest. It exerts the best impact on the economy and the largest promotion effect.

Adjust the Factor of Logistics Supply Capacity

Logistics actual supply capacity factor represents the actual utilization rate of assets such as existing logistics facilities. It is assumed that other variables remain unchanged. Based on Scheme 4, this study changes the logistics supply capacity. The logistics supply capacity factors in Scheme 4, Scheme 6 and Scheme 7 are 0.7, 0.5 and 1.0 respectively.

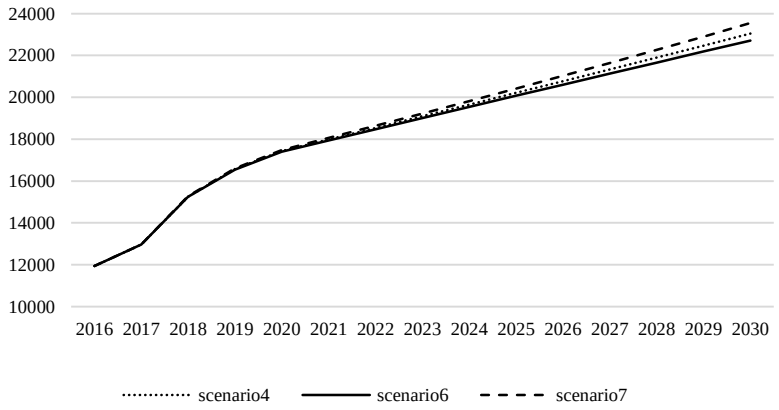

Figure 6: Influences of Different Logistics Supply Capacity Factors on GDP

As shown in Figure 6, when the logistics supply capacity factor is 0.5, GDP is the smallest. When the logistics supply capacity factor is 1.0, GDP is the largest. When the factor of logistics supply capacity is as large as possible, the actual utilization rate of logistics facilities is larger. Correspondingly, the GDP is higher. Logistics supply

capacity will affect GDP to a certain extent, and its positive effect on economic growth will become more prominent, and then promote steady economic development.

4. CONCLUSIONS AND DISCUSSION

By virtue of system dynamic simulation and simulation curve change, this study changes the economic hindrance factor, logistics demand conversion ability factor and logistics supply factor, and compares the development of GDP under different conditions. The following three conclusions are drawn.

At present, the logistics demand in Shanxi Province is developing rapidly, and the economic development has obviously greatly promoted the actual demand of logistics. 相 Correspondingly, it also drives the strengthening of logistics supply capacity.

Logistics development also plays a great role in promoting economic growth. With the improvement of logistics supply capacity and demand capacity, the amount of logistics obstacles decreases. The economy will also develop rapidly. Logistics is one of the pillars of the national economy, and its specialization plays an extremely important role in improving the quality of Chinese economic operation.

Increasing investment in logistics fixed assets is conductive to improving logistics supply capacity and reducing logistics backlog. At the same time, the system involves many parameters in real life. The change of some key parameters will greatly change the operation of the system. In order to improve the simulation effect, more accurate research such as quantitative analysis of relevant indicators should be carried out in the future.

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