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The Road of Post-Industrialization Transformation in Developing Countries Based on Weighted Markov and Grey Correlation Theory, Taking the Change of Industrial Structure in Heilongjiang Province of China as a Case Study

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Abstract: In the context of economic globalization, the comparative advantages of developing countries and developed countries tend to be more complex. After the economic crisis in 2008, the challenges of developing countries are intensified, and the game is more cyclical; Especially in the critical period when the "Fourth Industrial Revolution" is pending, many countries have increased their efforts in policy formulation and efficiency improvement, focusing on industrial transformation and upgrading, and closely combining structural reform with the industrialization process. Therefore, it is particularly important to analyze, change and forecast the industrial structure of post-industrial regions in developing countries based on data science algorithms, and to reshape the understanding of the adjustment of the world economic order and the evolution of the international trade division system. Based on the proportion of gross regional product and output value of three industries in Heilongjiang Province of China from 2001 to 2020, the minimum deviation model of industrial structure in Heilongjiang Province is constructed through Markov theory. The Lingo software is used to obtain the transition probability matrix of the industrial structure state, and combined with the autocorrelation coefficient of each order and the transfer weight, the change trend of the proportion of the output value of the three industries and the change of the contribution rate of the three industries (to GDP) in Heilongjiang Province in the next 10 years are obtained; At the same time, through the grey correlation index and spss software, this paper analyzes the correlation changes between the three industrial adjustments and economic development in Heilongjiang Province in the past 20 years, discusses the new growth points of economic development in Heilongjiang Province and puts forward corresponding suggestions for the adjustment of different industrial structures in Heilongjiang Province, and finally extends the general rules of the development of post-industrialization in the world. This article believes that it is necessary to adjust the structure of the first, second, and third industries reasonably based on different historical and natural endowments, contemporary backgrounds, and other practical factors, in accordance with local conditions, circumstances, and each with its own emphasis. At the same time, it also requires the support and inclination of government policies; Adapting industrial structure to local economic development while actively leading productivity and local economic development.

Keywords: industrial structure; Markov; grey correlation degree; economic develop

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1. Introduction

Currently, the global production capacity layout is undergoing major adjustments. Firstly, capital and production capacity in Northeast Asia (China, Japan, and South Korea) are moving southward towards Southeast Asia and South Asia; Secondly, European capital has shifted from west to east, turned east to west, and moved south to the Mediterranean

coast; The third is the construction of new industrial clusters in the Americas; The fourth is to expand production bases in Mexico and the Caribbean region of Central America. Observing these performances, we believe that there will be five new changes in the global industrial structure: firstly, the reduction of division of labor within the industrial chain and the shortening of the industrial chain. The second is the increase in industrial clusters and the enhancement of cooperation within regions and subregions. The third is international investment, with an increase in market orientation and a decrease in efficiency orientation. Fourthly, international trade in intermediate products has decreased, while trade in manufactured goods has increased. Fifth, international capital prefers green and blue economies. It is particularly important to analyze, change, and predict the industrial structure of post industrial regions in developing countries based on data science algorithms, and reshape the understanding of the adjustment of the world economic order and the evolution of the international trade division system.

The industrial structure is an important part of the national economic structure, and also a key structural system among the numerous structures within the social productivity system. The coordinated development of the industrial structure contributes to the stable growth of the national economy. With the economic development and the increase of national income, the labor force will be transferred from the primary industry to the secondary and tertiary industry. There are leading industries leading economic growth at all stages of economic growth, and leading industries can significantly drive economic development at this stage. A reasonable industrial structure has an important impact on the structure of social products, which is conducive to promoting the balance between total social supply and demand, and ultimately to optimizing the economic structure. The study of economic development and the evolution of industrial structure can reveal the relationship between industrial structure change and economic development, and is of great significance to regional development planning and macro-control, economic transformation and upgrading, and industrial structure optimization and adjustment.

For the quantitative and qualitative analysis of economic development and industrial structure, many domestic scholars have conducted research. Peng Jizeng et al. used grey theory to study the relationship between industrial structure and economic development in Jiangxi Province [1]. Ding Renzhong has improved the traditional growth rate decomposition method by combining deviation share analysis and price structure decomposition methods to conduct a nested decomposition of quantity and price for the economic growth of 19 urban agglomerations in China from 2000 to 2020, exploring the structural reasons for the economic differentiation between North and South from the perspective of urban agglomerations [2]. Tian Wenyong used grey correlation and regression analysis to calculate the degree of difference in the impact of internal industrial structure adjustments on agricultural economic growth in Guizhou Province from 1978 to 2012 [3]. On the basis of calculating and measuring the matching degree of resource allocation between China's local government's strategic emerging industry policies and capital markets, Feng Ruoyang uses China's inter provincial panel data to analyze and discuss the impact of the matching degree of local government's strategic emerging industry policies and capital market resource allocation on regional economic growth and its mechanism [4]. Zhao Peihua conducted an empirical study on the relationship between agricultural industrial structure adjustment and agricultural economic growth in Henan Province using EVIEWS 6.0 software and unit root test, cointegration test, and error correction model, using data from 2000 to 2019 as samples [5]. Guo Kesha analyzed the trend of changes in the structure of the secondary and tertiary industries in high-income economies during the upper and middle income stages and the early stages of entering the high-income stage, as well as their impact on the quality of economic development, in order to gain experience and inspiration for coordinating the development of the secondary and tertiary industries in China's new development stage and promoting high-quality development [6]. Hao Yuanyuan examines the process of industrial structure changes in the Yangtze River Delta region from 1989 to 2018 from the perspective of rationalization and upgrading of industrial structure, and constructs the

DCC-MGARCH model and ARDL model based on economic growth, energy consumption, and CO_2 emissions in the Yangtze River Delta region, as well as analyzes the impact of industrial structure changes on the transformation of regional economic growth patterns [7]. Liang Kunli used GMM and other methods to empirically study the impact of upgrading rural industrial structure on rural economic resilience, and further explored the role of infrastructure in it [8]. Wang Fulin et al. and Zhu Huixia et al. used Markov methods to scientifically predict the changes in the output structure of various industries in agriculture, forestry, animal husbandry, and fishing in China, as well as the changes in the industrial structure of the three northeastern provinces [9,10]. Zhao Dan and Yu Bin respectively built a minimum deviation model of industrial structure and an exponential smooth weighted Markov chain, and predicted the proportion of the three industrial output values in western Guizhou and the three industrial structures in Xiaoshan, Hangzhou in 2030 [11,12]. Wang Qing Constructs VAR Model and VECM Model to Study the Relationship between Fiscal Expenditure, Industrial Structure Optimization, and Economic Growth [13].

Compared with the traditional industrial structure prediction and analysis method which uses econometric model to analyze the time index series of industries, Markov theory prediction method solves the limitation of traditional industrial structure prediction and analysis methods that single index time series analysis cannot reveal the relationship between the three industries. By using Markov theory, the paper constructs the minimum deviation model of industrial structure in Heilongjiang Province, obtains the transition probability matrix of industrial structure state, and combines the autocorrelation coefficients and transfer weights of each order to obtain the change trend of the proportion of three industrial output values and the contribution rate of three industries (to GDP) in Heilongjiang Province in the next 10 years; At the same time, the grey correlation index is used to analyze the correlation changes between the three industrial adjustments and economic development in Heilongjiang Province in the past 20 years, explore the new growth points of economic development in Heilongjiang Province, and seek the countermeasures to better transform the economic development mode of Heilongjiang Province. Finally, the paper puts forward specific strategies to optimize the industrial structure of Heilongjiang Province.

This article believes that it is necessary to adjust the structure of the first, second, and third industries reasonably based on different historical and natural endowments, contemporary backgrounds, and other practical factors, in accordance with local conditions, circumstances, and each with its own emphasis. At the same time, it also requires the support and inclination of government policies; Adapting industrial structure to local economic development while actively leading productivity and local economic development. Assist in analyzing, changing, and predicting the industrial structure of post industrial regions in developing countries based on data science algorithms, reshaping understanding of the adjustment of the world economic order and the evolution of the international trade division system.

2. Current Situation of Development and Industrial Structure Transformation in Heilongjiang Province

Heilongjiang Province is an important old industrial base in China. Heilongjiang Province is a big manufacturing province with coal, oil, wood, machinery and food as the leading industries. Traditional industries such as agriculture, resources, energy and equipment manufacturing are the main driving force to promote the economic development of Heilongjiang Province. Heilongjiang Province has made great contributions to promoting China's industrialization. The province has formed an industrial structure layout with resource development and heavy industry as the main body for a long time, and has a good foundation in equipment industry, petrochemical industry, food and medicine industry and energy (Table 1).

Table 1. Main Indicators of the National Economy of Heilongjiang Province in 2020.

Main Indicators of the National Economy of Heilongjiang Province.					
Index	Unit	Absolute Amount	Increase	Proportion Nationwide	Proportion to the Total Industrial Output Value of the Province
population	ten thousand people	3171	−4.48%	2.2%	
GDP	billion	13,698.5	1.0%	1.35%	
primary industry	billion	3438.3		4.42%	
the secondary industry	billion	3479.4		0.91%	
tertiary industry	billion	6780.8		1.22%	
grain yield	10000 tons	7540.8		11.3%	
Industrial electricity consumption	twh	598.47			
Fixed assets investment			3.3%		
Total retail sales of social consumer goods	billion	5092.3			
Per capita disposable income of urban residents	yuan	31,115			
Per capita disposable income of rural residents	yuan	16168			
Consumer price index Index		102.3			
Total industrial output value of mining industry	ten thousand yuan	14,585,950			16.1%

In recent years, the grain output of Heilongjiang Province has ranked first in the country, and the "ballast" status of safeguarding national food security is prominent. In 2021, the refining capacity will exceed 25 million tons, the conversion rate of agricultural products will be greatly improved, Shenhua Guoneng Baoqing Power Plant will be put into operation, and the development of graphite, steel, copper and other mineral resources will be accelerated. A number of landmark projects, such as Shenzhen (Harbin) Industrial Park, have taken root, and the infrastructure support capacity has been significantly enhanced.

But at the same time, there are also some problems and pressures in the development of Heilongjiang Province in recent years: for example, the downward pressure on economic development is great, the people's welfare needs to be strengthened and improved, the level of openness and cooperation needs to be improved, the system and mechanism need to be further improved, and the brain drain problem is more serious. The problems of economic development in terms of volume, quality, speed and endogenous power need to be solved. The following is an analysis of the problems in the development of the three industries from the perspective of Figure 1.

The proportion of the primary industry in the three industries fluctuated slightly in some years, but the overall trend (2001–2020) is steadily increasing. During the epidemic in 2020, the economy slowed down. As a dominant industry in Heilongjiang, agriculture stabilized the "basic plate" of economic growth. In 2020, the primary industry contributed 66.5% to the GDP of the province. However, the primary industry in Heilongjiang Province is faced with the problems of imperfect system and system construction, low added value and low modernization. First, the output price of agriculture, forestry, animal husbandry and fishery fluctuates greatly under the influence of domestic and foreign import and export markets and macro-control policies, and the economic benefits of farmers are unstable. For example, in 2022, several auctions of domestic soybeans for junior high school grain storage appeared. Heilongjiang has 60% of the national soybean planting area. Longjiang soybeans

are famous for its adherence to non GMO high-quality, but its output lags behind that of American soybeans, squeezing the market. For another example, policy reforms such as price protection and temporary collection and storage of corn once brought about "low grain prices hurt farmers", resulting in overcapacity and unreasonable planting structure. Second, mechanization and intensification of agriculture, forestry, animal husbandry and fishery, and low conversion rate of scientific and technological achievements. Information technology, e-commerce logistics, municipal supervision, laws and regulations, financial insurance and other forces failed to fully benefit farmers, dealers, consumers and other sectors in the whole chain of agriculture, forestry, animal husbandry and fishery industry. Third, the infrastructure of agriculture, forestry, animal husbandry and fishery is backward, which is greatly affected by natural disasters. The protection of agriculture, forestry, animal husbandry and fishery resources (such as black soil vegetation and other animal and plant ecosystems) is not enough. The development of agriculture, forestry, animal husbandry and fishery carbon sink projects, related characteristic brands and characteristic ecotourism is not mature.

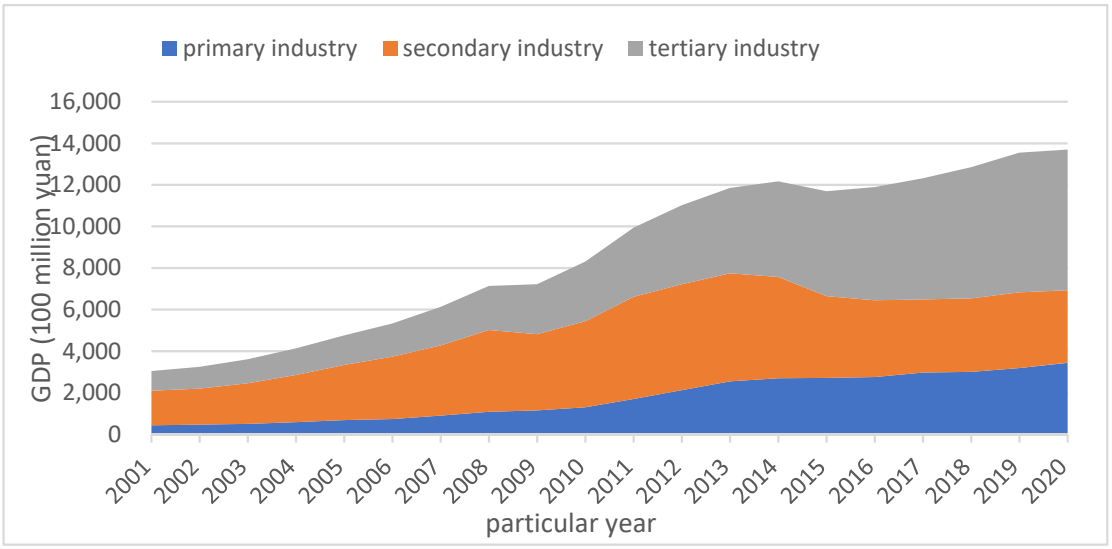

Figure 1. GDP of three industries in Heilongjiang Province from 2001 to 2020.

The internal structural contradiction of the secondary industry is prominent. For a long time, the resource industries or resource processing and manufacturing industries in Heilong Province are still highly concentrated, and the development and changes of individual resource (coal and oil) cities affect the economic volume and structure changes of the whole province. There are fewer high value-added products for fine and deep processing, and the development level of high-tech industries and light industries is low and small. The processing industry is mainly composed of coal, oil, wood and other raw materials, which are relatively at the low end of the industrial chain. Since 2013, the proportion of the secondary industry in the province has gradually declined, bringing about passive surpassing of the tertiary industry. By 2020, the proportion of the secondary industry will be reduced to 25.4%, a serious decline. The decline in the proportion of the secondary industry is due to internal and external factors. The first external factor is that the high frequency fluctuation of international bulk commodities and global energy prices leads to the decline of oil prices, coal prices and grain prices, which makes economic development rather passive. Second, the changes in the national economic and political situation, the impact of the need for national strategic adjustment, transformation and upgrading, such as supply side structural reform, coal capacity control, output restriction, etc., are likely to affect Heilongjiang Province, which takes the output of resource products and means of production as an important industrial support; The first internal factor is that the geographical location is remote and cold for a long time, and the transportation

capacity is insufficient and resources are facing exhaustion. Second, the equipment cost of heavy industrial enterprises is high and the renewal is slow, and the elderly care burden of the aging enterprise personnel is heavy. Third, there is a lack of technical, financial and information talents, and the concept of systems and mechanisms is conservative and rigid. The industrial industry of Heilongjiang Province is still in the middle stage, which needs to be improved in terms of both quality and efficiency, and needs to be developed with high quality.

The tertiary industry has advanced development and the overall development level is low. In recent years (2013–2019), the tertiary industry in Heilongjiang Province has developed rapidly. In 2019, the tertiary industry accounted for 49.6%, lower than the national average of 54.5%. In the same year, the tertiary industry contributed 65.1% to the economic growth of the province. The proportion of the tertiary industry in 2020 will be 49.5%, which is not significantly lower than that in 2019. Compared with the other two industries, the proportion of the tertiary industry will still be relatively high. At the same time, the contribution of the tertiary industry to economic growth in 2020 will become negative, dropping sharply to −49.7% (see Figure 2). This shows the growth of the proportion of the tertiary industry in Heilongjiang Province in recent years (2013–2019). The structural change of the economy is not entirely due to the economic development, partly because of the sluggish industrial economic development. The tertiary industry has surpassed passively in the proportion of the industrial structure. Its advanced development has overdrawn the sustainable development ability of Heilongjiang and covered up the downward problem of industrial development. The development of the internal structure of the tertiary industry is unreasonable. The added value mainly exists in traditional service industries such as wholesale and retail, accommodation and catering, transportation, warehousing and postal services. These industries are often most vulnerable to the impact of the epidemic; However, such high-tech industries as consulting information services, real estate and medical care, artificial intelligence, and financial insurance are lack of vitality and innovation, with low added value. At the time of the epidemic, the tertiary industry in Heilongjiang Province has been greatly impacted, and its anti risk ability is low. This shows that the development of the tertiary industry in Heilongjiang Province has some problems, such as low quality, low economic benefits, and unstable contribution to the regional GDP. The tertiary industry has not yet become the leading and pillar industry to stimulate local economic growth.

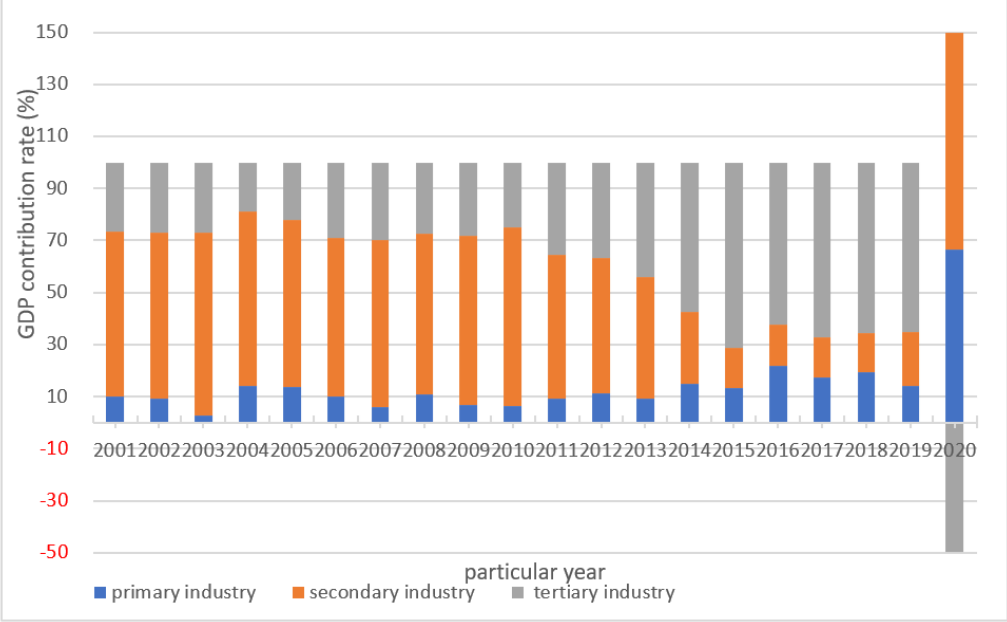

Figure 2. Contribution rate of three industries in Heilongjiang Province to GDP from 2001 to 2020.

3. Research Methods

3.1. Prediction Method of Industrial Structure and Industrial Contribution Rate Markov Prediction Model

3.1.1. Introduction to Markov Forecasting Model

Markov process was developed by A AMarkov was first proposed and studied in 1906, and its theory has been very perfect since its development. It is an important branch of the field of stochastic processes. Its characteristics are: the future is only affected by the current rather than the past, and its prediction accuracy is relatively high, which is particularly prominent among the solutions to many prediction problems.

If any $n > 1$, arbitrarily $i_1, i_2, i_3 \ldots i_{n-1}, j \in s$,Constant existence of:

$$P\{X_n = j \,/\, X_1 = i_1, X_2 = i_2 \ldots X_{n-1} = i_{n-1}\} = P\{X_n = j \,/\, X_{n-1} = i_{n-1}\} \quad (1)$$

Then the discrete stochastic process $\{Xt, t \in T\}$ is called Markov chain.

3.1.2. Determination Method of Markov State Transition Probability Matrix and Weight

Suppose the observed output value structure of three industries is shown in Table 2. $yj(t)$ refers to the proportion of $j(j = 1, 2, 3)$ industry in GDP at time t.

Table 2. Proportion of output value structure of each industry.

Time (t)	**Proportion of Output Value Structure of Each Industry** $yi(t)$		
	$y1(t)$	$y2(t)$	$y3(t)$
0	$y1(0)$	$y2(0)$	$y3(0)$
1	$y1(1)$	$y2(1)$	$y3(1)$
2	$y1(2)$	$y2(2)$	$y3(2)$
3	$y1(3)$	$y2(3)$	$y3(3)$
⋮	⋮	⋮	⋮
m	$y1(m)$	$y2(m)$	$y3(m)$

The transfer probability matrix estimated according to the principle of least square method is;

$$P = \begin{pmatrix} P_{11} & P_{12} & \ldots & P_{1n} \\ P_{21} & P_{22} & \ldots & P_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ P_{n1} & P_{n2} & \ldots & P_{nn} \end{pmatrix}$$

Then the fitting error of the jth industrial output value in the total regional output value at time t is:

$$e_j(t) = y_j(t) - \sum_{i=1}^{3} p_{ij} y_j(t-1) \qquad j = 1, 2, 3 \quad (2)$$

The square sum of the fitting error of the jth industry value in the proportion of the total regional output value in the whole observation period Q_j is:

$$Q_{\mathrm{j}} = \sum_{t=1}^{3} [\mathrm{e}_j(t)]^2 \quad (3)$$

The sum of squares of fitting errors for primary industry, secondary industry and tertiary industry in the whole observation period Q is:

$$Q = \sum_{j=1}^{3} Q_j = \sum_{j=1}^{3} \sum_{t=1}^{m} [e_j(t)]^2 \quad (4)$$

The following nonlinear programming model is established to determine the minimum value of Q, and then the transition probability matrix p_{ij} and transition weight of industrial structure state are obtained:

(1) Objective function:

$$\text{Min } Q = \sum_{j=1}^{3} \sum_{t=1}^{m} [y_j(t) - \sum_{i=1}^{3} p_{ij} y_j(t-1)]^2 \quad (5)$$

(2) Constraints:

$$\sum_{j=1}^{3} p_{ij} = 1 \qquad i = 1, 2, 3 \quad (6)$$

$$P_{ij} \geq 0 \qquad i, j = 1, 2, 3 \quad (7)$$

(3) Autocorrelation coefficients and transfer weights of each order [14]. When the lag is selected, the autocorrelation coefficient r_k and transfer weight w_k of each order are calculated respectively (Table 3):

Table 3. Autocorrelation coefficient and transfer weight of each order.

Project	Order				
	1	**2**	**3**	**4**	**5**
rk	0.5647	0.3444	0.2309	0.1105	0.1417
wk	0.4056	0.2474	0.1658	0.0794	0.1018

3.2. Grey Relevancy

Grey correlation analysis is a relative ranking analysis, which is used to quantitatively study the correlation degree of various factors within the system with time and space changes. From the perspective of thinking, the grey correlation analysis mainly judges the correlation degree between factors by comparing the geometric intuitive performance of each factor. The specific analysis steps are as follows:

(1) Take the studied factors as the reference sequence $x = (x_1, x_2, x_3, x_4 \ldots x_n)$ and the other factors as the subsequences $x_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4} \ldots x_{in})$, and initialize each sequence. The sequence after initialization is:

$$G_i = (g_{i1}, g_{i2}, g_{i3} \ldots g_{in}) = (\frac{x_{i2}}{x_{i1}}, \frac{x_{i3}}{x_{i1}}, \ldots \frac{x_{in}}{x_{i1}}) \quad (8)$$

(2) Calculate the absolute difference between reference sequence and sub sequence at the same time, and find out the maximum and minimum values:

$$E = \text{minmin}|g_{1t} - g_{it}| \quad (9)$$

$$F = \text{maxmax}|g_{1t} - g_{it}| \quad (10)$$

(3) The grey correlation coefficient of subsequence x_i and x_1 at the first time is:

$$\lambda_{il} = \frac{E + \mu F}{|g_l - g_{il}| + \mu F} \quad (11)$$

(4) The above equation λ is the correlation coefficient. The resolution coefficient of u grey correlation coefficient is usually 0.5, E and F are two levels of minimum difference and two levels of maximum difference. Generally, the average value of grey correlation degrees is taken as the correlation degree, and the calculation formula of the correlation degree is:

$$\varphi i = \frac{1}{n} \sum_{l=1}^{n} \lambda_{il} \quad (12)$$

4. Empirical Analysis

4.1. Prediction of the Proportion of Output Value of Three Industries in Heilongjiang Province

According to the 2021 Statistical Yearbook of Heilongjiang Province as the data source, and using the relevant data of gross regional product (GDP) from 2001 to 2020, the proportion of industrial output value is shown in Table 4.

Table 4. Proportion of output value of three industries in Heilongjiang Province from 2001 to 2020.

Particular Year	Primary Industry	Secondary Industry	Tertiary Industry
2001	14.0%	54.7%	31.3%
2002	14.3%	53.3%	32.4%
2003	13.7%	54.2%	32.1%
2004	14.1%	54.9%	31.0%
2005	14.2%	55.8%	30.0%
2006	13.7%	56.3%	30.0%
2007	14.6%	55.2%	30.2%
2008	15.1%	55.2%	29.7%
2009	15.8%	50.8%	33.4%
2010	15.5%	49.9%	34.6%
2011	17.1%	49.5%	33.4%
2012	19.2%	46.3%	34.5%
2013	21.4%	43.9%	34.7%
2014	22.1%	40.0%	37.9%
2015	23.2%	33.6%	43.2%
2016	23.1%	31.0%	45.9%
2017	24.1%	28.6%	47.3%
2018	23.4%	27.5%	49.1%
2019	23.5%	26.9%	49.6%
2020	25.1%	25.4%	49.5%

According to the data in Table 4, the state transition $P_{ij} \geq 0$ probability can be established $(i, j = 1, 2, 3)$ the nonlinear programming model of is as follows:

$$\text{Min } Q = \sum_{j=1}^{3} \sum_{t=1}^{m} [y_j(t) - \sum_{i=1}^{3} p_{ij} y_j(t-1)]^2 \tag{13}$$

restraint condition:

$$\sum_{j=1}^{3} p_{ij} = 1 \qquad i = 1, 2, 3 \tag{14}$$

$$P_{ij} \geq 0 \quad i, j = 1, 2, 3 \tag{15}$$

Lingo software is used to solve nonlinear planning, and the operation interface is shown in Figure 3 below:

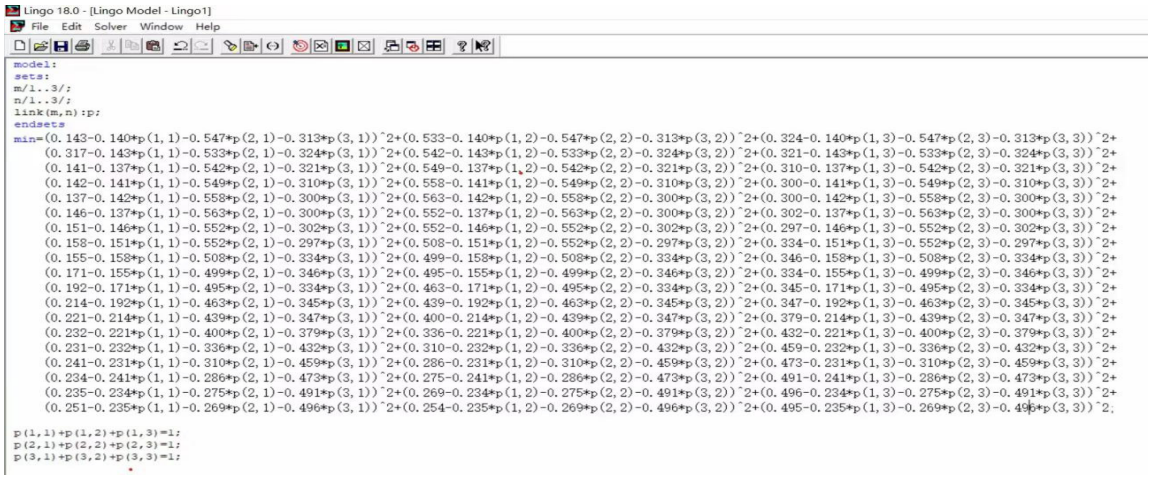

Figure 3. Code input operation interface for lingo to solve nonlinear programming model.

The state transition matrix is obtained as follows:

$$p_{ij}^{1} = \begin{pmatrix} 0.438 & 0 & 0.562 \\ 0.035 & 0.963 & 0.002 \\ 0.266 & 0 & 0.734 \end{pmatrix} p_{ij}^{2} = \begin{pmatrix} 0.341 & 0 & 0.659 \\ 0.050 & 0.927 & 0.023 \\ 0.312 & 0 & 0.688 \end{pmatrix}$$

$$p_{ij}^{3} = \begin{pmatrix} 0.325 & 0 & 0.675 \\ 0.061 & 0.893 & 0.047 \\ 0.320 & 0 & 0.680 \end{pmatrix} p_{ij}^{4} = \begin{pmatrix} 0.322 & 0 & 0.678 \\ 0.071 & 0.860 & 0.070 \\ 0.321 & 0 & 0.679 \end{pmatrix}$$

Combining the autocorrelation coefficient r_k and the transfer weight w_k, the lag time is selected [14]. It can be calculated to predict the proportion of the three industrial output values of Heilongjiang Province from 2021 to 2030, as shown in Table 5 (including the predicted values from 2021 to 2023) and Figure 4 (including the predicted values from 2021 to 2030).

Table 5. Prediction of Output Value Ratio of Three Industries in Heilongjiang Province from 2021–2023.

Initial Time	Steplength	Weight	Primary Industry	Secondary Industry	Tertiary Industry
2016	5	0.1018	23.1%	31.0%	45.9%
2017	4	0.0794	24.1%	28.6%	47.3%
2018	3	0.1658	23.4%	27.5%	49.1%
2019	2	0.2474	23.5%	26.9%	49.6%
2020	1	0.4056	25.1%	25.4%	49.5%
Forecast value in 2021			24.9%	24.8%	50.3%
Forecast value in 2022			25.2%	23.8%	51.0%
Forecast value in 2023			25.4%	22.9%	51.6%

According to the prediction in Table 5 and Figure 4:

(1) In 2021, the proportion of primary industry output value will decline slightly.From 2022 to 2030, the proportion of the output value of the primary industry will increase slightly and steadily year by year, while the proportion of the output value of the secondary industry will decline.

(2) From 2021 to 2030, the proportion of the output value of the tertiary industry in Heilongjiang Province will continue to increase. Taking 2016–2020 as the initial

forecast year, it can be predicted that the proportion of the output value of the tertiary industry in Heilongjiang Province will reach 60% by 2042.

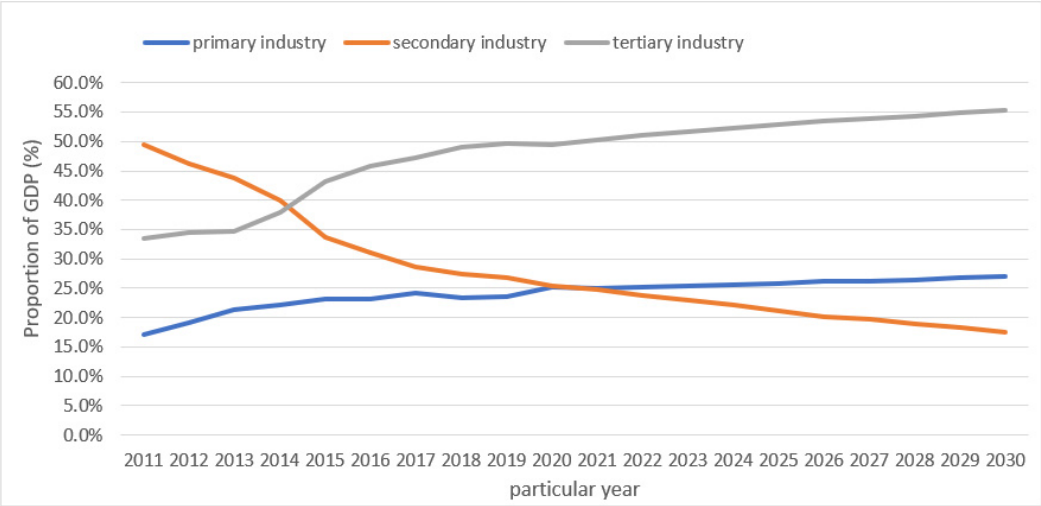

Figure 4. Trend Figure 4. Chart of Output Value Proportion of Three Industries in Heilongjiang Province from 2001 to 2030 (including 2021–2030 predicted values).

4.2. Prediction of the Contribution Rate of Heilongjiang's Three Industries to the Regional GDP

According to the 2021 Statistical Yearbook of Heilongjiang Province as the data source, and using the relevant data of gross regional product (GDP) from 2001 to 2020, the contribution ratio of each industry to GDP is shown in Table 6.

Table 6. Contribution ratio of three industries to GDP in Heilongjiang Province from 2001 to 2020.

Particular Year	Primary Industry	Secondary Industry	Tertiary Industry
2001	14.0%	54.7%	31.3%
2002	14.3%	53.3%	32.4%
2003	13.7%	54.2%	32.1%
2004	14.1%	54.9%	31.0%
2005	14.2%	55.8%	30.0%
2006	13.7%	56.3%	30.0%
2007	14.6%	55.2%	30.2%
2008	15.1%	55.2%	29.7%
2009	15.8%	50.8%	33.4%
2010	15.5%	49.9%	34.6%
2011	17.1%	49.5%	33.4%
2012	19.2%	46.3%	34.5%
2013	21.4%	43.9%	34.7%
2014	22.1%	40.0%	37.9%
2015	23.2%	33.6%	43.2%
2016	23.1%	31.0%	45.9%
2017	24.1%	28.6%	47.3%
2018	23.4%	27.5%	49.1%
2019	23.5%	26.9%	49.6%
2020	25.1%	25.4%	49.5%

According to the data in Table 6, the state transition $P_{ij} \geq 0$ probability can be establishe $(i, j = 1, 2, 3)$ the nonlinear programming model of is as follows:

$$\text{Min } Q = \sum_{j=1}^{3} \sum_{t=1}^{m} [y_j(t) - \sum_{i=1}^{3} p_{ij} y_j(t-1)]^2 \quad (16)$$

restraint condition:

$$\sum_{j=1}^{3} p_{ij} = 1 \qquad i = 1,2,3 \tag{17}$$

$$P_{ij} \geq 0 \qquad i,j = 1,2,3 \tag{18}$$

Lingo software is used to solve nonlinear planning, and the operation interface is shown in Figure 5 below:

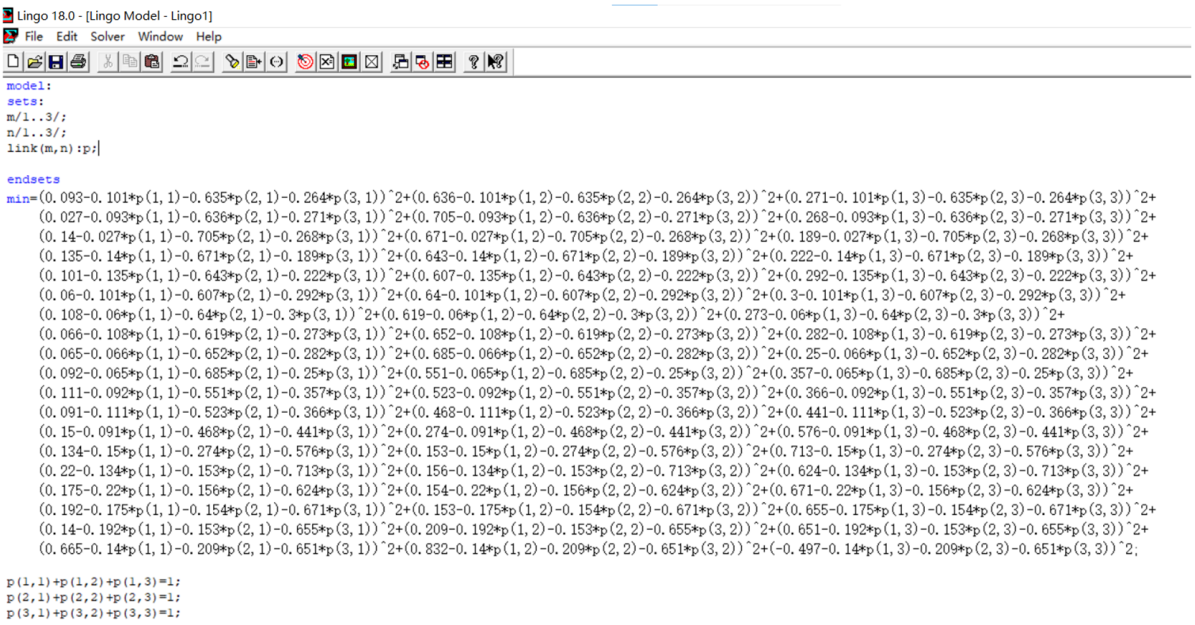

Figure 5. Code input operation interface for lingo to solve nonlinear programming model.

The state transition matrix is obtained as follows:

$$p_{ij}^{1} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0.886 & 0.114 \\ 0.370 & 0.158 & 0.472 \end{pmatrix} \tag{19}$$

Thus, according to this state transition matrix, the following can be obtained:

$$p^{2}{}_{ij}, p^{3}{}_{ij}, p^{4}{}_{ij}, p^{5}{}_{ij} \tag{20}$$

I will not repeat it here. Similarly, the autocorrelation coefficient and transfer weight [14] can be used to calculate and predict the proportion of the three industries' contribution to GDP in Heilongjiang Province from 2021 to 2030, as shown in Table 7 (including the predicted value from 2021 to 2023) and Figure 6 (including the predicted value from 2021 to 2030.

According to the prediction in Table 6 and Figure 6:

(1) The contribution rate of the primary industry output value of Heilongjiang Province to the regional GDP will return to the third place in 2021;
(2) Compared with 2020, the contribution rate of the output value of the secondary industry to the GDP of Heilongjiang Province will decline in 2021, and the contribution rate is slightly lower than that of the tertiary industry. From 2022 to 2030, although the contribution rate of the secondary industry output value in Heilongjiang Province will fluctuate slightly, the contribution rate of the secondary industry output value will remain the first among the three industries;
(3) The contribution rate of the tertiary industry output value to the regional GDP in Heilongjiang Province will increase in 2021 compared with 2020. From 2022 to 2030,

although the contribution rate of the tertiary industry's output value will fluctuate slightly, it will remain the second among the three industries.

Table 7. Prediction of Contribution Ratio of Three Industries to GDP in Heilongjiang Province from 2021–2023.

Initial Time	Steplength	Weight	Primary Industry	Secondary Industry	Tertiary Industry
2016	5	0.1018	22.0%	15.6%	62.4%
2017	4	0.0794	17.5%	15.4%	67.1%
2018	3	0.1658	19.2%	15.3%	65.5%
2019	2	0.2474	14.0%	20.9%	65.1%
2020	1	0.4056	66.5%	83.2%	−49.7%
Forecast value in 2021			3.0%	47.7%	49.3%
Forecast value in 2022			18.2%	50.0%	31.8%
Forecast value in 2023			11.6%	49.4%	39.0%

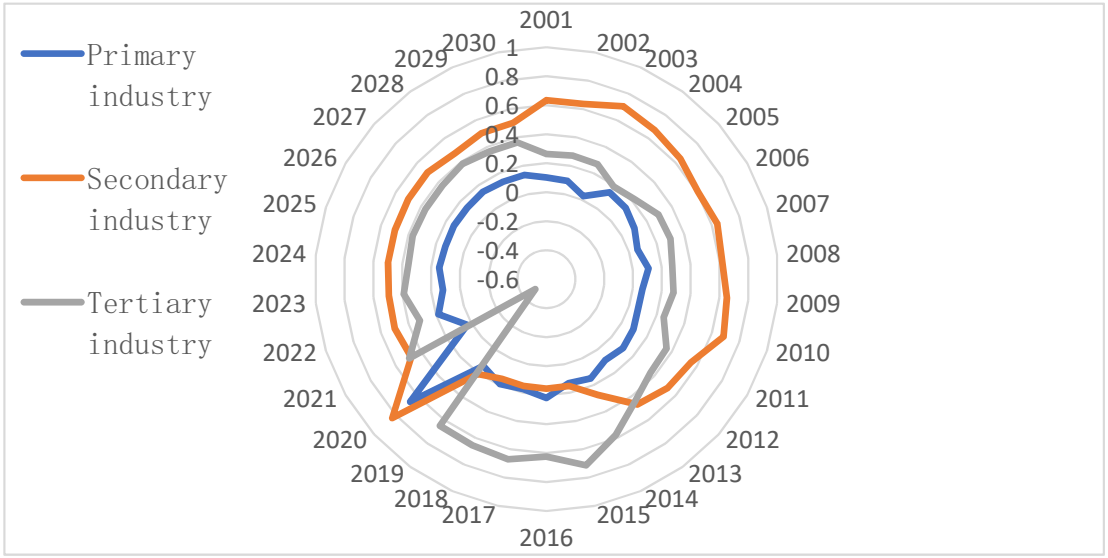

Figure 6. Prediction of Contribution Ratio of Three Industries to GDP in Heilongjiang Province from 2021–2030 (including 2021–2030 predicted values).

Forecast, analysis and summary [15–17]:

In 2020, the contribution of the tertiary industry to the GDP will decline to a negative value due to various factors. It shows that the tertiary industry in Heilongjiang Province does not have the strength to lead the economic development for a long time, the quality of the modernization, transformation and upgrading of the industrial structure is not enough, the contribution of the tertiary industry to the GDP is not stable, and there are problems such as being greatly affected by the external economic and social environment.

It is predicted that in the post epidemic era after 2020, the secondary industry still needs to make contributions to the regional GDP. In the future, the development of the secondary industry will play a role in contributing to the local economy and have a strong anti risk ability.

Only by consolidating the leading role of industry in economic development, building a new industrial system and strengthening the supporting role of the primary and secondary industries can the tertiary industry play its due role. At the same time, we should also

improve the internal structure of the tertiary industry and develop the tertiary industry with high quality, so that the tertiary industry can play its due role.

4.3. Relevance between Industrial Structure and Economic Development in Heilongjiang Province

The grey system theory puts forward the concept of grey correlation analysis for each subsystem, which aims to seek the numerical relationship between each subsystem (or factor) in the system through certain methods. Therefore, the grey relational analysis provides a quantitative measure for the development and change of a system, and is very suitable for dynamic history analysis.

According to the 2021 Statistical Yearbook of Heilongjiang Province as the data source, using the relevant data of gross regional product (GDP) from 2001 to 2020, and with the help of SPSS analysis software, we can draw the following Figures 7 and 8 [18–20]:

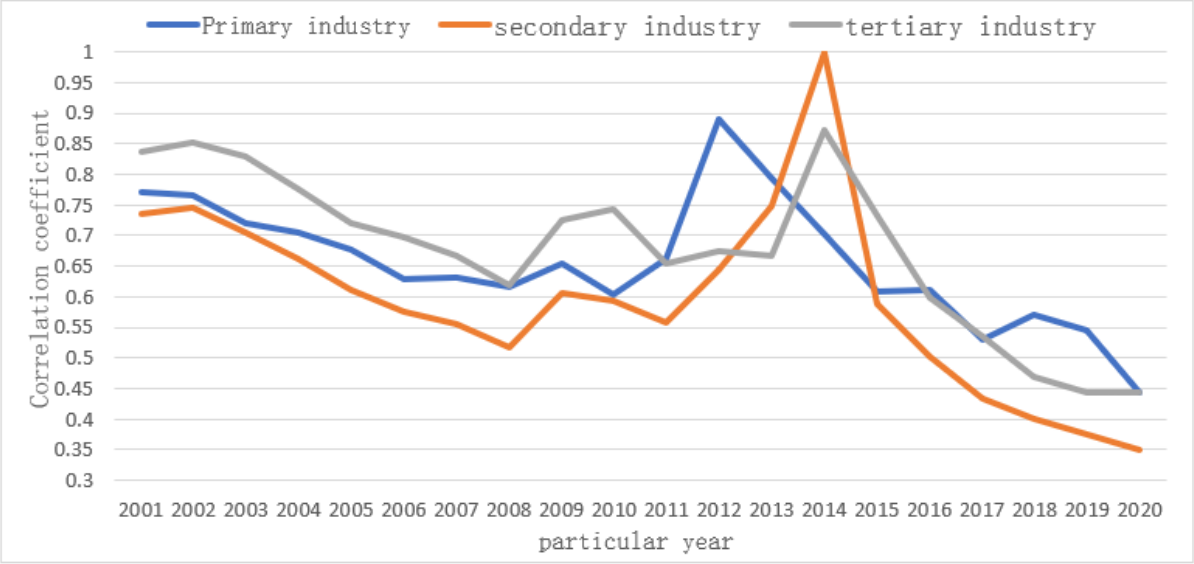

Figure 7. Correlation coefficient of three industries in Heilongjiang Province from 2001 to 2020.

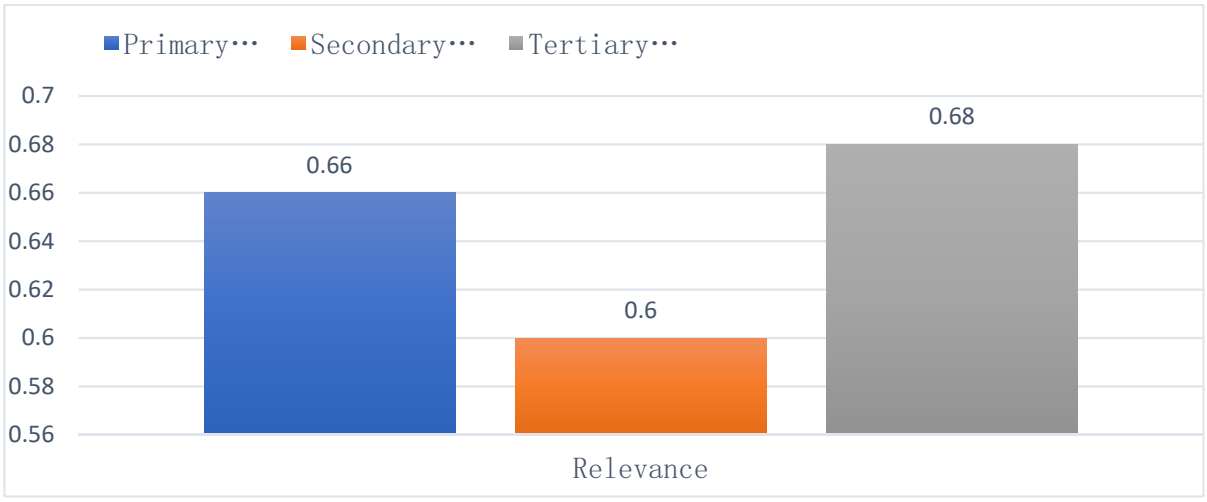

Figure 8. Grey Correlation of Three Industries in Heilongjiang Province from 2001 to 2020.

According to the grey correlation between the three industrial structures and economic development level of Heilongjiang Province from 2001 to 2020 in Figures 7 and 8 [21–23]:

(1) During the 20 years from 2001 to 2020, the correlation between the tertiary industry and the level of economic development in Heilongjiang Province was the highest

among the three industries, indicating that the economic development of Heilongjiang Province in this period generally depended on the tertiary industry;

(2) During the 20 years from 2001 to 2020, the correlation between the primary industry and the level of economic development in Heilongjiang Province was slightly lower than that of the tertiary industry, but also ranked second with a relatively high correlation.

The period 2001–2020 is roughly divided into four stages (refer to Figure 7), and the situation analysis is summarized as follows:

From 2001 to 2011, the grey correlation between the three industrial structures and the level of economic development in Heilongjiang Province was "three one two": In 2003, the CPC Central Committee and the State Council issued and implemented the "Several Opinions on Implementing the Revitalization Strategy of Old Industrial Bases in Northeast China". Under the new era background of the CPC Central Committee and the State Council, the revitalization plan of old industrial bases in Northeast China and the leadership of the State Council, the reform of the system and mechanism in Heilongjiang Province has achieved initial results, the transformation of value-added tax, agricultural tax relief Major reforms, such as the policy bankruptcy of state-owned enterprises and the exemption of enterprises from historical tax arrears, have brought about the initial optimization and upgrading of the industrial structure; But at the same time, in 2008, in response to the financial crisis, the stimulus policy represented by huge investment was adopted, and the potential of economic growth was overused and used in advance, resulting in disorderly development and destruction of resources, which led to capacity expansion, overcapacity and the overall debt level in the short term. The phenomenon of economic foam appeared [24–26].

From 2011 to 2013, the grey correlation between the three industrial structures and the level of economic development in Heilongjiang Province was "one, three, two" or "one, two, three": the primary industry was highly correlated with the local economic development. In 2011, the total grain output of Heilongjiang Province surpassed that of Henan Province for the first time and became the largest province in China. In 2012, Heilongjiang Province again became the largest province in China in terms of grain production. The average annual growth rate of total grain output and per capita share ranked first in China. In order to ensure national food security, Heilongjiang Province has made great contributions and agricultural development is in the ascendant. At the same time, due to the implementation of macro-control policies on real estate, the real estate investment in Heilongjiang Province has slowed down. By 2012, the consumption demand brought by "home appliances to the countryside" and "agricultural machinery to the countryside" has become saturated. The increase of people's awareness of environmental protection, the increase of national oil prices, and the decline of auto industry sales have led to a decline in investment and consumption, which has adversely affected the subsequent economic growth [27–29].

From 2013 to 2015 and from 2015 to 2020, the grey correlation between the three industrial structures and the level of economic development in Heilongjiang Province was "two, three, one" and "one, three, two": After 2014, the correlation between the secondary industry and regional economic growth dropped sharply. The long-term deep-seated institutional structural problems, the impact of overlapping cyclical factors and the international and domestic political and economic situation, as well as the impact of the need for national strategic adjustment, transformation and upgrading: such as changes in international kerosene and grain prices, supply side structural reform, coal production capacity control and output restrictions, etc., Heilongjiang, which takes the export of resource products and means of production as an important industrial support, has been seriously affected. The development of key resource (coal and petroleum) cities affects the total economic output and structural changes of the province. At the same time, affected by the epidemic, it is difficult for regional economic growth to rely on the tertiary industry, which has low quality, unreasonable internal structure and unbalanced regional development [30–32].

In 2017–2020, the gray correlation between the three industrial structures and the level of economic development in Heilongjiang Province was "one, three, two": economic growth depends more on the primary industry, Heilongjiang Province earnestly shouldered the political responsibility of maintaining national food security, and the achievements of poverty alleviation were effectively linked with rural revitalization, which promoted the continuous income increase of farmers. However, the increase in grain production has not accelerated the pace of industrial development. At present, the grain in Northeast China is still rarely processed locally, and the ability of self processing and deep processing of grain needs to be improved. At the same time, the epidemic in 2020 also exposed many weaknesses in the development of the tertiary industry. The internal structure and regional distribution of the tertiary industry are uneven. There are traditional mechanisms and systems (such as regional blockade, industry segmentation management) in the traditional service industry. The conflicts of interest in material circulation, commodity exchange, and market management are prominent, which is difficult to bring scale benefits. The standardization and specialization of procurement, distribution, sales, business decision-making and other functions, as well as the standardization and intensification of business flow, logistics and information flow, need to be further strengthened [33].

5. Conclusions and Suggestions

By using Markov theory, the paper constructs the minimum deviation model of industrial structure in Heilongjiang Province, obtains the transition probability matrix of industrial structure state, and combines the autocorrelation coefficients and transfer weights of each order to obtain the change trend of the proportion of three industrial output values and the contribution rate of three industries (to GDP) in Heilongjiang Province in the next 10 years; At the same time, using the grey correlation index, this paper analyzes the correlation changes between the three industrial adjustments and economic development in Heilongjiang Province in the past 20 years.

Adjustment of industrial structure in developing countries. Adjusting industrial structure is a global trend, and developing countries are no exception. But due to the different original industrial structures. Therefore, there are significant differences in the tasks and adjustment steps faced. In the historical process of the industrial revolution, developing countries have been latecomers. When developed countries took the lead in implementing the new technological revolution, most developing countries have not yet completed the task of traditional industrialization.Therefore, compared to developed countries, the adjustment of industrial structure in developing countries not only has its own special regulations, but also varies depending on the situation of each country, time, and place.

Adjustment of industrial structure in raw material producing countries. In order to avoid deteriorating trade conditions for raw materials and primary products, raw material producing and exporting countries have begun to establish processing industries and improve the degree of product processing. According to statistics, between 1970 and 1980, the proportion of "unprocessed and unprocessed" products in developing country exports decreased from 52.5% to 43%, while the proportion of "processed and ready for final use" products increased from 25.4% to 39.9%.middle Eastern oil exporting countries have utilized huge oil revenues to establish downstream industries for crude oil and natural gas, and have achieved significant results in replacing crude oil and natural gas exports with oil and natural gas products. In order to diversify and achieve balanced economic development, many countries are embarking on establishing other industrial sectors to increase self-sufficiency. For example, Iran and Iraq have developed industrial sectors such as smelting, construction materials, pharmaceuticals, and papermaking, especially Iran. They have also built household appliance industrial enterprises such as refrigerators, televisions, and air conditioners.

Industrial restructuring in export oriented countries. Some developing countries belong to export-oriented economies, with production oriented towards international markets

and imports for export. In recent years, due to the decreasing demand for labor-intensive products in the international market, technology intensive industries have begun to develop. For example, Singapore has been implementing the "Second Industrial Revolution" since 1979, with the upgrading of the manufacturing industry as the leading factor, comprehensively promoting mechanization, automation and computerization, and focusing on the development of the electronic industry. South Korea began implementing a strategy of expanding exports and increasing imports of substitute products from the second five-year plan (1967–1971). Later, with the development of the manufacturing industry, it gradually expanded exports of machinery, electronics, building materials, and other products to drive the development of the entire industry through exports.

At present, Singapore, South Korea, India, Brazil, China's Hong Kong, Taiwan Province and other countries and regions are starting to develop the electronic computer, ocean engineering, optical fiber industry. South Korea has more than 500 factories engaged in the production of electronics, computers, precision machinery and instruments. The electronic industrial products exported by India account for 7% of the total export value. In 1983, the export revenue of household appliances and electronic components in Taiwan Province exceeded that of textiles. We have briefly described the adjustment of industrial structure in several types of developing countries. In addition to developing traditional industries, developing countries also bear the daunting task of establishing emerging industries.

Some major developing countries and countries with strong industrial foundations are successively establishing institutions for the development of science and technology to accelerate research and development of new technologies. For example, in India, the National Bioengineering Bureau was established in 1982, and the National Science and Technology Personnel Employment Bureau and National Science and Technology Exchange Committee were established in 1983. In 1982, a plan was formulated to develop the electronic industry in the 1980s, emphasizing the research and development of large-scale integrated circuits. The Indian government is also building an electronic city on the outskirts of Garol, the capital of Karnataka, which has a relatively developed electronic industry, using the "Silicon Valley" model in California, USA. The Indian government announced a new computer policy on 19 November 1984, which stipulated preferential protection measures for the development of the country's computer industry.

Some export-oriented newly industrialized country and regions are accelerating the introduction of new technologies, transforming traditional labor-intensive industries and developing technology intensive industries. For example, in South Korea, at the end of 1984, the "Medium and Long Term Plan for National Policy Research and Development" was passed, which stipulated the investment of 27,000 senior researchers and the allocation of 40 billion Korean won from 1985 to 1991 to accelerate the research and development of cutting-edge technologies. Its important research topics include electronic computers, new active substances, microelectronics technology, advanced and automation of the mechanical industry, localization of strategic materials, genetic engineering, etc. South Korea pays attention to digestion and absorption while introducing technology, implements localization, and transforms traditional industries accordingly.

The adjustment of the industrial structure in developing countries is a long-term and arduous task, which is far from being completed and has uneven development. However, many developing countries have achieved significant results in adjusting their industrial structure and are beginning to enter a period of sustained economic growth. This can undoubtedly serve as a model for those who follow suit.

Due to uncontrollable factors such as the frequency and volume of data release, government macro-control, and changes in internal and external economic environment, the effectiveness of the prediction and analysis results may not be completely consistent with the real situation, but it can still reflect the overall trend of economic development. At the same time, the following analysis results are obtained:

The primary industry is an advantageous factor in the economic development of Heilongjiang Province. As a basic industry of the national economy, it has a high grey

correlation degree with the local economic development level (the grey correlation index is 0.66) over the past 20 years, which has made positive contributions to the local economic growth. At the same time, it is predicted that the proportion of the output value of the primary industry will increase steadily in the future, and the primary industry should be strengthened while expanding.

The secondary industry is a key factor in the economic development of Heilongjiang Province. It is predicted from the calculation that the contribution of the secondary industry's output value will continue to stay in the top position in the future (with a contribution of about 50%). In the future, the secondary industry of Heilongjiang Province will play an irreplaceable role in the economic development, and its development cannot be blindly suppressed. According to the prediction, the proportion of the output value of the secondary industry has shown a downward trend, and its gray correlation with the economic development has also shown a downward trend in recent years (to 0.35 in 2020), indicating that the industrial industry in Heilongjiang Province is still in the middle stage, and needs to be improved in terms of both quality and efficiency. We should firmly maintain the leading and pillar position of the secondary industry, and accelerate the transformation from heavy industry to new industrialization, Achieve the rapid development of industrial enterprises with high quality.

The tertiary industry is a potential factor in the economic development of Heilongjiang Province. The prediction and research analysis show that the tertiary industry maintains a high level of contribution and correlation to GDP, and its potential to stimulate economic growth is huge. The tertiary industry should constantly optimize its internal structure and improve its quality and efficiency. According to the forecast analysis, the proportion of the output value of the tertiary industry is on the rise, but the proportion of the output value of the tertiary industry in Heilongjiang Province will exceed 60% for a long time (to 2042). While accelerating the pace of industrial upgrading and adjustment, it also needs strong national policy support and tilt.

At the same time, combined with previous theoretical and empirical studies, the paper analyzed the development of three major industries in post-industrial areas of developing countries from three perspectives, and finally reached the following policy recommendations:

(1) We will deepen the supply side structural reform of agriculture, constantly improve the level of agricultural and rural modernization, promote the integrated development of the entire agricultural industry chain, improve the modernization of farmland infrastructure, and improve the agricultural production standard system. Build a modern circulation system of agricultural products and a new type of agricultural socialized service system. Strengthen the construction of small and medium-sized farmland water conservancy facilities, carry out the whole process mechanization improvement action, improve the intelligent level of agricultural machinery and equipment, and accelerate the development of rice seedling greenhouse, intelligent greenhouse and other facilities agriculture. We will improve the modern agricultural science and technology innovation system, accelerate breakthroughs in a number of key technologies in the prevention and control of major animal epidemics, black land protection, and comprehensive utilization of straw, and promote the construction of agricultural science and technology parks. Enlarge the advantages of non transgenic, cold black soil and green organic, and accelerate the formation of characteristic agricultural brand pattern. We will vigorously implement the modern seed industry upgrading project, introduce agricultural, forestry, animal husbandry and fishery carbon sequestration projects, and promote the industrialized application of biological breeding. Strengthen the protection, development and utilization of agricultural germplasm resources, improve the quality and safety inspection and detection system of agricultural products, fully implement the digital agriculture development strategy, promote the development of the whole industrial chain of animal husbandry,

and further increase the proportion of animal husbandry output value in the total agricultural output value [34,35].

(2) We will accelerate the construction of a modern industrial system, strengthen the position of industrial enterprises as the basic industries of the province, promote the upgrading of the industrial base and the modernization of the industrial chain, create advantageous industrial clusters, and promote the intensive and efficient development of industrial parks. Develop and deeply process mineral resources such as coal, oil and gas, steadily develop the coal industry, properly develop the coal power industry, highlight the development of the coal chemical industry, focus on the development of new material industries such as graphite, break through advanced basic processes in the fields of manufacturing technology and material preparation, and break through a batch of industrial basic software in the fields of intelligent terminal operating system, industrial Internet, etc. Focusing on key complete machine products and high added value products, we will organize upstream and downstream enterprises to strengthen industrial coordination and technical cooperation to tackle key problems, cultivate a group of leading enterprises with leading power in industrial ecology, form advanced manufacturing clusters, and drive the optimization and upgrading of the entire industrial chain. The development of the secondary industry plays a role in contributing to economic growth. We should speed up the construction of a new industrial system, form a pattern of multiple pulling and multiple supporting alternative industries, enhance the industrial linkage driving effect and technological progress spillover effect in the process of economic growth, strengthen the power of economic growth, and accelerate the construction of a strong industrial province [36,37].

(3) Accelerate the development of modern service industry, and promote the extension of productive service industry to the high-end of specialization and value chain. The upgrading of industrial structure has a long period of time. We will accelerate the pace of industrial upgrading based on policy, accelerate the development of industrial design, information consulting, modern logistics, legal services and other industries, and promote the deep integration of modern service industry with advanced manufacturing industry and modern agriculture. We will optimize the internal structure of the tertiary industry and the layout of urban and rural consumption networks, and create a safe and secure consumption environment and a market-oriented, legal and international business environment. We will deepen the reform of market-oriented factor allocation, transform government functions, improve the quality and efficiency of state-owned enterprise reform, stimulate the development of non-public economy, and optimize the development environment of private economy. We will effectively solve the problems of traditional mechanisms and systems within the traditional service industry, and foster new technologies, new formats, and new models. Deepen the reform of the science and technology management system, and efficiently allocate technology, talents, capital and other innovative elements. We will strengthen demand side management, strengthen fiscal, tax and financial reform, improve capital market financing, lead a low-carbon and circular economy model, and expand effective investment. We will improve the control of binding indicators for environmental protection, energy conservation and emission reduction, strengthen the brand building of ecotourism, and constantly improve the level of opening up [38,39].

Looking at the grey correlation between the three industrial structures and the level of economic development in Heilongjiang Province in the past 20 years, the economic development of Heilongjiang Province is more affected by uncertainties at home and abroad. We should pay close attention to the situation of macroeconomic development at home and abroad, establish a macroeconomic monitoring and early warning system, and provide predictive information and long-term vision for the development planning and macro-control, economic transformation and upgrading, and industrial structure optimization and adjustment of Heilongjiang Province [40].

In recent years, Heilongjiang Province seizes the opportunity of a new round of scientific and technological revolution and industrial transformation, vigorously develops digital economy, biobased economy, ice and snow economy and creative design industry, cultivates and expands strategic emerging industries such as aerospace and new materials, and forms a new industrial layout with multiple supports and simultaneous development of multiple industries.with the approval of the State Council, the Fourteenth Five Year Plan for the Comprehensive Revitalization of the Northeast issued by the National Development and Reform Commission defines the key tasks, policies and projects for the comprehensive revitalization of the Northeast during the Fourteenth Five Year Plan period, and systematically and comprehensively defines the direction, policies and key initiatives for the revitalization of the Northeast. The future of Heilongjiang is worth looking forward to.

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