Study of Multiple Linear Regression on the Technology Upgrading of Sichuan Province by Mathematical Statistics and Computational Science

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Abstract. China's economy has entered a new normal, and the industrial structure must be upgraded in order to realize the transformation of economic growth kinetic energy. Sichuan Province, as the economic leader in western China, needs to accelerate the optimization of its industrial structure. Therefore, this paper makes an empirical analysis of the factors that affect the upgrading of Sichuan's industrial structure, and puts forward countermeasures and suggestions to promote the optimization of Sichuan's industrial structure.

Keywords: Rationalization of industrial structure, High industrial structure, multiple linear regression

1. Introduction
Since 2015, China's economy has entered a new normal, and the problem of economic structural differentiation is obvious. It is urgent to promote the optimization of China's industrial structure in order to achieve sustained, stable and rapid economic growth in China. Sichuan Province, as the economic center of western China, plays an important role in the strategic layout of national economic development and shoulders the heavy responsibility of promoting the western development strategy. In the "Made in China 2025 Sichuan Action Plan" published by the Sichuan Provincial Government, it is pointed out that Sichuan is currently facing industrial structure problems such as overcapacity in traditional industries and great pressure to upgrade industrial structure. To realize the goal of "transforming from a big economic province to a strong economic province", Sichuan must optimize and upgrade its industrial structure, and promote its rationalization and high-level development. Therefore, this paper measures the industrial structure rationalization degree (RIS) and industrial structure heightening degree (AIS) in Sichuan Province, measures the industrial structure upgrading level in Sichuan Province, and makes an empirical analysis on the factors that affect the industrial structure upgrading in Sichuan Province. On this basis, it puts forward some countermeasures and suggestions to promote the industrial structure optimization in Sichuan Province.
2. Data description and index calculation

2.1. Data description
This paper selects the relevant data of Sichuan Province from 2005 to 2018 for processing and analysis. The original data comes from Sichuan Statistical Yearbook, Sichuan Census Data Compilation, Statistical Yearbook and Statistical Bulletin of each city, and relevant public data collation.

2.2. Rational structure of production
Rationalization of industrial structure mainly refers to the strengthening of inter-industry coordination ability and the improvement of correlation level, which is the objective requirement of economic coordination and sustained growth. At present, scholars mainly demonstrate the rationality of industrial structure through international comparison method, shadow price analysis method and demand judgment method, and take international benchmark, demand structure benchmark and inter-industry proportional balance benchmark as judgment standards, but these methods and standards have certain limitations in empirical analysis. Inter-industry coordination is the central content of industrial structure rationalization, and inter-industry coordination involves the distribution of various production factors among industries. After literature research, this paper selects the distribution of labor factors among the three industries to examine the coordination between industries, specifically draws on Li Xin's research model, and replaces the international standard three industry structure in the Hamming closeness measurement method with the employment structure between industries. To measure the differences between industries under compatible industrial structure and employment structure [1], the model formula is:

$$RIS = 1 - \frac{1}{3} \sum_{i=1}^{3} \frac{|Y_i - L_i|}{Y}$$

(Yi/Y represents the ratio of output value to total output value in three industries, and Li/L represents the ratio of employed labor force to total labor force in three industries. Obviously, the greater the coordination between industries, the closer the ratio of Yi/Y and Li/L is. This means that the closer RIS is to 1, the closer the industrial structure is to employment structure, and the higher the rationalization level of industrial structure in this region. The variation trend of RIS value from 2005 to 2018 calculated by formula (1) and the collected data is shown in Figure 1. As can be seen from Figure 1, from 2005 to 2018, the rationalization level of industrial structure in Sichuan Province decreased due to the impact of economic recession in 2008, and showed a steady upward trend in other years, but after 2016, the growth rate of rationalization level slowed down significantly.)

Data source: public information collation
On the whole, the rationalization level of Sichuan's industrial structure fluctuates less and the rationalization degree is better. However, compared with Jiangsu Province and other eastern developed regions, the rationalization level of Sichuan Province is still relatively low. Under the same model algorithm, the RIS value of Jiangsu Province in 2016 is close to 0.92, while that of Sichuan Province is less than 0.83. Obviously, Sichuan Province still has a large space for improvement in promoting the rationalization of industrial structure.

2.3. Advanced industrial structure

The upgrading of industrial structure refers to the dynamic process in which the industrial structure develops from low level to high level by changing the dominant position among industries. The main performance is that the industry evolves from low added value to high added value, and progresses along the dominant position from the primary industry to the secondary and tertiary industries. The dominant position of an industry can be measured by the standard of industrial output value, and the industry with significant industrial ratio is the dominant industry. The proportion of output value of three industries in Sichuan Province from 2005 to 2018 is shown in Figure 2. It can be seen from Figure 2 that during the ten years from 2005 to 2015, Sichuan's industry generally maintained the "second, third and first" industrial structure, with the secondary industry as the leading industry. In 2016, the proportion of the tertiary industry exceeded that of the secondary industry, and the output value of the tertiary industry accounted for 51.4% in 2018. The tertiary industry has gradually become the leading industry in Sichuan Province.

In order to more clearly show the process of the industrialization of Sichuan Province, this paper draws on the experience of Tao Changqi and others and uses the ratio of the output value of Sichuan’s tertiary industry and secondary industry to measure the level of industrialization of Sichuan Province. The specific formula is [2]:

$$AIS = \frac{GDP_3}{GDP_2}$$

(2)

According to formula (2) and the data of Sichuan Provincial Bureau of Statistics, the industrial structure of Sichuan from 2005 to 2018 is highly upgraded, as shown in Figure 3. It can be seen from Figure 3 that the level of industrial structure upgrading in Sichuan is fluctuating and rising, and the AIS value has exceeded 1 for three consecutive years after 2015. It can be seen that Sichuan's industrial
structure has basically transitioned from a low level to a high level, and gradually increased its high level with the economic development.

![Figure 3](image-url)  
**Figure 3.** Changes in the level of industrialization in Sichuan Province from 2005 to 2018

3. The key factors and empirical analysis of industrial structure upgrading in Sichuan Province

The main factors affecting regional industrial structure are regional factor endowment, demand structure orientation, inter-regional economic ties and production concentration. Regional economic development level, high-quality labor force, capital factors, financial development level, opening-up level and innovation ability are the key factors to promote the upgrading of industrial structure. In this paper, combined with the theory of industrial structure upgrading, the representative indicators of key factors are selected, and an empirical model is constructed by using R language to objectively judge the influence of the above seven key factors on the rationalization and upgrading of industrial structure in Sichuan Province.

3.1. Variable selection and variable descriptive statistics

Combined with the above analysis and considering the applicability and availability of data, the specific indicators selected in this paper are as follows:

① In this paper, the GDP (X1) of Sichuan Province represents the economic development level of Sichuan Province as an explanatory variable. Because the upgrading of industrial structure can drive economic growth, and the degree of economic development also promotes the change of industrial structure [3].

② Since fixed capital investment can directly affect the supply structure of the region and then adjust the original industrial structure, the fixed assets investment amount (X2) of Sichuan in that year is selected as an index to measure the endowment of regional capital factors and as an explanatory variable.

③ Select the total balance index (X3) of each loan in Sichuan in that year to express the degree of regional financial development as an explanatory variable. On the one hand, the financial sector can optimize the market operation mechanism of regional economy, on the other hand, it can play a role in the allocation of other resources with the help of financial resources. The upgrading of regional industrial structure is inseparable from the expansion of financial scale [4].

④ In view of the fact that the optimization of international trade structure and international investment structure is an important part of industrial structure optimization, Sichuan's total net exports (X4) and total foreign direct investment (X5) are selected as indicators to measure the degree of regional openness, and they are both explanatory variables.
⑤ The ratio of the number of fresh graduates of undergraduate, master's and doctor's degrees to the total labor force in Sichuan in that year (X6) is selected as an explanatory variable to reflect the influence of the regional labor structure on the upgrading of industrial structure.

⑥ Select the number of valid invention patents (X7) of enterprises above designated size in Sichuan in that year as the measure index of regional innovation capability and as the explanatory variable. On the one hand, innovation can cause the transfer of production factors among industries, leading to the contraction or expansion of departments, and directly affect the development of industrial structure. On the other hand, innovation can change the relative income of production factors and living and working conditions, thus indirectly affecting the industrial structure.

⑦ RIS and AIs are selected as the explanatory variables of the seven explanatory variables. Through empirical analysis, seven explanatory variables are used for regression analysis of RIS and AIS, and the influence of the above key factors on the rationalization and upgrading of industrial structure is investigated.

The raw data of each index comes from the public information of Sichuan Provincial Bureau of Statistics, National Bureau of Statistics, Ministry of Commerce of China and People's Bank of China. Taking into account the stability of the variables, the economic development level, total fixed capital investment, total loan balance, total net export, foreign direct investment amount and patent index are processed logarithmically. The descriptive statistics of each variable are shown in Table 1 below.

### Table 1. Statistical description of main variables

| variable | Variable interpretation | standard deviation | mean value | minimum | Maximum |
|----------|-------------------------|--------------------|------------|---------|---------|
| lnX1     | Regional economic development level | 0.5329             | 9.8794     | 8.9072  | 10.6134 |
| lnX2     | Value of total fixed capital investment | 0.7244             | 9.5596     | 8.1541  | 10.4737 |
| lnX3     | Total loan balance       | 0.6689             | 9.9652     | 8.8163  | 10.8985 |
| lnX4     | Net export value         | 0.7329             | 15.0714    | 13.5800 | 16.0119 |
| lnX5     | Value of foreign direct investment | 1.0621             | 14.2370    | 11.9121 | 15.5884 |
| X6       | Proportion of high quality labor force | 0.0857             | 0.0428     | 0.0254  | 0.0594  |
| lnX7     | Number of patents of Enterprises above Designated Size | 1.2202             | 8.7063     | 6.7979  | 10.4901 |
| RIS      | Rationalization level of regional industrial structure | 0.6124             | 0.8134     | 0.7907  | 0.8333  |
| AIS      | High level of regional industrial structure | 0.1740             | 0.9628     | 0.7833  | 1.3699  |

Data source: R language 4.0 calculation results

3.2. Empirical process and empirical result analysis

(1) Correlation test

In order to measure the correlation between the above seven key factors and between each factor and the upgrading level of industrial structure (RIS and AIS), this paper analyzes the correlation between seven independent variables and two dependent variables, and the analysis results are shown in Table 2.

### Table 2. Correlation coefficient matrix of each variable

|       | lnX1   | lnX2 | lnX3    | lnX4    | lnX5    | X6   | lnX7   | RIS    | AIS    |
|-------|--------|------|---------|---------|---------|------|--------|--------|--------|
| lnX1  | 1.0000 |      |         |         |         |      |        |        |        |
| lnX2  | 0.9921 | 1.0000 |        |         |         |      |        |        |        |
| lnX3  | 0.9962 | 0.9937 | 1.0000 |         |         |      |        |        |        |
| lnX4  | 0.9694 | 0.9653 | 0.9531 | 1.0000 |         |      |        |        |        |
| lnX5  | 0.9789 | 0.9701 | 0.9637 | 0.9933 | 1.0000 |      |        |        |        |
| X6    | 0.7062 | 0.7405 | 0.6945 | 0.7201 | 0.7653 | 1.0000 |        |        |        |
| lnX7  | 0.9831 | 0.9709 | 0.9806 | 0.9473 | 0.9387 | 0.8947 | 1.0000 |        |        |
| RIS   | 0.9237 | 0.8986 | 0.9142 | 0.8398 | 0.8803 | 0.6873 | 0.9271 | 1.0000 |        |
| AIS   | 0.6298 | 0.6107 | 0.6657 | 0.4708 | 0.5906 | 0.3798 | 0.7267 | 0.7328 | 1.0000 |

Data source: R language 4.0 calculation results
According to the correlation coefficient matrix shown in Table 2, it can be seen that: First, the correlation coefficients of the seven variable indexes with RIS and AIS are all positive, which is in line with economic significance. Secondly, the correlation coefficient among the variables is on the high side, and the variables are highly correlated, so it is impossible to simply carry out multiple regression analysis on all the variables.

(2) Multiple linear regression estimation

The two empirical models established in this paper are to study the influence of the above seven indicators on the rationalization level of industrial structure RIS and the high-level AIS of industrial structure. Therefore, in the empirical process, the seven variables were regressed with RIS and AIS respectively. Because of the multicollinearity among the variables, this paper adopts the stepwise regression method, and selects the regression model with the minimum AIC value with the aid of AIC information criterion. Finally, the influencing factor model of industrial structure rationalization and the influencing factor model of industrial structure heightening are selected.

① Rational return of industrial structure

The estimated results of the constructed regression model for rationalization of industrial structure are shown in Table 3.

Table 3. Regression estimation results on the rationalization model of industrial structure

| variable | regression coefficient | Standard error | Pr(|t|) |
|----------|------------------------|----------------|--------|
| C        | 7.525485               | 0.040678       | 0.000332*** |
| lnX1     | 5.125424               | 0.026058       | 0.000956*** |
| lnX3     | 3.057124               | 0.017125       | 0.008720* |
| lnX4     | 1.259978               | 0.005462       | 0.001030* |
| X6       | 2.230946               | 0.177364       | 0.002252* |

$R^2=0.9424$, $Pr(|F|)=0.002794$, $AIC=2.130627$, $DW=2.436225$

Data source: R language 4.0 calculation results

According to the regression results, the model with multicollinearity retains four independent variables, namely, the logarithm of regional economic development level, the logarithm of total loan balance, the logarithm of total net exports and the proportion of high-quality labor force. These four influencing factors explain 94.24% of the rationalization level of Sichuan's industrial structure, the model fits well, and passes the F test and T test at a 95% confidence level. At the same time, the DW value of the model is 2.436225, there is no autocorrelation, and it passes the test. According to the regression results, get the regression equation:

$$RIS=5.125424lnX1+3.057124lnX3+1.259978lnX4+2.230946X6+7.525485$$

It can be seen from the regression equation that the regional economic development level (X1), regional financial development level (X3), net export trade (X4) and high-quality labor force ratio (X6) of Sichuan Province have a positive effect on the rationalization of regional industrial structure the impact is in line with economic logic and reality. Among them, the level of regional economic development (X1) has an extremely significant impact on the level of regional industrial rationalization, which means that when the GDP of Sichuan Province increases by 1%, the rationalization level of Sichuan's industrial structure can be increased by 0.05125424 units. Generally speaking, the proportion of high-quality labor has the greatest impact on the rationalization level of industrial structure, followed by the level of regional economic development, and the least affected by the level of regional financial development. Therefore, paying attention to training and attracting high-quality talents in Sichuan is
conducive to promoting the coordination of industrial factors in Sichuan, narrowing the technical fault and labor productivity gap between related industries, so as to improve the rationalization level of Sichuan's industrial structure.

② The return of industrial structure

By using the same method, multiple linear regression analysis is conducted on AIS of industrial structure upgrading level. The estimation results of the regression model of industrial structure upgrading are shown in Table 4.

Table 4. Regression estimation results of the advanced industrial structure model

| variable | regression coefficient | Standard error | Pr>|t| |
|----------|------------------------|----------------|-------|
| C        | 1.282148               | 0.190428       | 0.000082*** |
| lnX1     | 7.492524               | 0.003794       | 0.000846*** |
| lnX2     | 4.447174               | 0.005018       | 0.002025**  |
| lnX5     | -1.619784              | 0.001372       | 0.000502*** |
| X6       | 1.737589               | 0.12261        | 0.002266*** |
| lnX7     | 8.094832               | 0.001661       | 0.004065**  |

\[ \text{Data source: R language 4.0 calculation results} \]

According to the regression results, the advanced model of industrial structure after eliminating multicollinearity retains the measurement of regional economic development level (X1), regional capital factor endowment (X2), foreign direct investment level (X5), and the proportion of high-quality labor force (X6) Five independent variable indicators of regional innovation capacity (X7). The DW value is 1.984658, and the model passes the correlation test, and there is no autocorrelation. Passed f test and t test at the same time. The adjusted R2 of the model is 99.94%, which shows that the model has a high degree of fitting and has a significant impact under the confidence interval of 99%. Finally, the regression equation of industrial structure heightening is:

\[ \text{AIS} = 7.492524 \ln \text{X1} + 4.447174 \ln \text{X2} - 1.619784 \ln \text{X5} + 1.737589 \ln \text{X6} + 8.094832 \ln \text{X7} + 1.282148 \]

According to the AIS multiple linear regression equation, all the variables except for direct investment (X5) have a positive impact on the industrial structure of Sichuan. When other conditions remain the same, for every 1% increase in Sichuan's GDP, the level of Sichuan's industrial structure can be increased by 0.07492524 units. When other conditions remain unchanged, an increase of 1% in Sichuan’s fixed capital investment can increase the level of Sichuan’s industrial structure to a high level of 0.04447174 units; while other conditions remain unchanged, increasing the ratio of high-quality labor to 1 unit can increase the level of industrial structure 1.737589 Units. When other conditions remain unchanged, a 1% increase in regional innovation capacity can contribute 0.08094832 units to increase the level of industrial structure. However, if other conditions remain unchanged, a 1% increase in foreign direct investment in Sichuan will reduce the level of industrial structure heightening by 0.01619784 units. On the whole, a region's economic development level, high-quality labor talents and regional innovation ability have relatively great influence on upgrading the industrial structure, while capital endowment has little influence. The process of industrial structure upgrading is a process in which the output value ratio of the tertiary industry and the secondary industry gradually increases, which actually requires the tertiary industry to accelerate its development. The effect of regional economic level on the upgrading of industrial structure is usually indirect. Only when the economy develops to a certain extent can the total investment and consumption demand in this region increase and the consumption level increase accordingly, thus indirectly promoting the development of the tertiary industry. High quality labor force and innovation ability have both direct and indirect effects on the upgrading of industrial
structure. High quality labor talents and innovation ability represent higher labor productivity and technical level, which help to promote the development of regional technology intensive industries, and then enhance the level of industrial structure. According to the report on the development of foreign invested enterprises in Sichuan Province published by Sichuan Economic Cooperation Bureau from 2005 to 2019, foreign investment is mainly concentrated in the secondary industry, and the manufacturing industry is the industry with the highest concentration of foreign-invested enterprises over the years. In the early stage of China's industrialization, foreign investment did promote the development of China's industry. However, with the deepening of industrialization, on the one hand, the original advantage of cheap labor gradually disappeared, and the ability to attract foreign investment declined. On the other hand, large-scale foreign investment is concentrated in the secondary industry, which plays a positive and positive role in upgrading the industrial structure from the dominant position of the primary industry to the dominant position of the secondary industry. However, when the industrial structure develops to a higher level, too much foreign capital concentrated in the secondary industry is not conducive to the upgrading of the industrial structure. Therefore, from 2005 to 2018, the model reflects that the effect of foreign direct investment in Sichuan on the upgrading of regional industrial structure is significantly negative.

4. Conclusions and Countermeasures

4.1. Conclusions

According to the above analysis, the rationalization level and upgrading level of industrial structure in Sichuan Province have been greatly improved from 2005 to 2018, and some achievements have been made in upgrading industrial structure, but compared with the developed areas in the east, there is still much room for upgrading. From 2005 to 2018, regional capital factor endowment, regional financial development degree, net export, international investment and regional innovation ability do not all have significant impact on the rationalization and upgrading of industrial structure. The level of regional economic development and the proportion of high-quality labor force have a great positive impact on the rationalization and upgrading of industrial structure.

The two indicators of the degree of opening to the outside world, total net exports and total foreign direct investment, have different effects on the upgrading of industrial structure. In the model of industrial rationalization, FDI has no significant effect, but the total net export has a significant positive effect on the level of industrial rationalization. In the model of industrial structure upgrading, the total net exports have no significant impact, but the impact of foreign direct investment on industrial structure upgrading is negative. The negative effect mainly lies in that the concentration of foreign capital in the secondary industry is not conducive to the flow of resources to the tertiary industry.

4.2. Countermeasures

(1) Ensure high quality economic growth

The results of empirical analysis show that the level of regional economic development has a great positive impact on industrial upgrading, and improving the level of economic development is conducive to the upgrading of industrial structure. And the optimization of industrial structure can promote economic growth. They form a positive feedback loop, which is beneficial to the long-term development of the economy. Although there are many criticisms in academic circles that policy objectives only attach importance to GDP growth, but not to development quality. However, from the empirical results of optimizing industrial structure by using GDP, the increase of GDP has a significant positive effect on the rationalization and upgrading of industrial structure. Therefore, it is suggested that the Sichuan Provincial Government can neither only adopt GDP theory nor pay attention to GDP growth when formulating economic policy objectives. The policy should focus on establishing a benign economic development path: by deepening supply-side reforms, promoting industrial structure upgrades while ensuring quality economic growth, and then reusing economic increments to ensure economic stock reforms, and further optimizing industrial structures.

(2) Increase human capital investment and enhance employment attraction
The disappearance of demographic dividend and the increasing degree of aging are the common labor supply problems faced by the whole country. Only by increasing investment in human capital, improving education level and expanding education popularization rate can we cultivate high-quality labor force. Solve the imbalance between labor supply and demand by improving labor productivity. According to the 2018 Yearbook of China's Population and Employment Statistics and the 2018 Yearbook of China's Social Statistics, the average years of education of the labor force in Sichuan Province in 2018 is 10.68 years, which is equivalent to the high school level. According to the empirical results, the high-quality labor force with bachelor degree or above is the key factor to promote the upgrading and optimization of industrial structure. It can be seen that Sichuan still needs to pay attention to the accumulation of human capital. On the one hand, it is suggested to continue to strengthen the investment in higher education and cultivate talents suitable for the upgrading of industrial structure. On the other hand, we should enhance the employment attraction of Sichuan, create a talent gathering highland in the west, and promote the infrastructure construction and social service level, create a livable environment, attract talents to flow in and stay behind, and accelerate the upgrading of Sichuan's industrial structure.

(3) Enhance the level of opening to the outside world and enhance the efficiency of foreign capital utilization

Reform and opening up is an important means to promote China's industrialization. However, China's industrialization has entered the middle and late stages, and the requirements of China's economic development have shifted from quantity to quality. Accordingly, the level of opening up and the efficiency of foreign capital utilization should be improved. According to the empirical model, FDI in Sichuan Province has hindered the upgrading of local industrial structure. Therefore, it is suggested that Sichuan should improve the level of opening to the outside world and focus on enhancing the efficiency of foreign capital utilization. In terms of import and export, it is suggested to increase the import of advanced technology and equipment, from product import to technology import. At the same time, optimize the export structure, enhance Sichuan's position in the global industrial chain, and develop from exporting low value-added intermediate products to exporting high value-added intermediate products. With regard to the utilization of foreign capital, we should optimize the investment environment, attract foreign capital, guide foreign capital to the tertiary industry at the same time, and upgrade the industrial structure.

References

[1] Li Xin. Analysis of the influencing factors of the industrial structure upgrade of Jiangsu Province [J]. Journal of Jiangsu Vocational College of Economics and Trade. 2018(05): 21-24
[2] Tao Changqi, Peng Yongzhang. Analysis of the spatial effect of technological innovation intensity on industrial structure upgrade under economic agglomeration [J]. Industrial Economic Research, 2017(03): 91-103.
[3] Sun Yuebing. An empirical study on the relationship between industrial structure upgrading and economic growth [D]. Chongqing Technology and Business University, 2015.
[4] Xie Shaoqi. Research on the influence of financial scale of Jiangxi Province on industrial upgrading [D]. Jiangxi University of Finance and Economics, 2017.
[5] Liu Bo. Research on the Impact of Sichuan Labor Force Changes on the Upgrading of Industrial Structure [D]. Sichuan Academy of Social Sciences, 2018.