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Analysis of the non-linear impact of innovation capacity on industrial structure

Sijia Zhao*, Shijia Tang

Institute of Economics, Beijing Technology and Business University, Beijing, 102401, China
**Corresponding author: jia08609@163.com*

Abstract: *Promoting industrial structure upgrade, upgrading industrial structure and solving the contradictions existing in industrial structure are the key concerns of economic development in this era. Based on this, this paper takes 30 provinces, municipalities directly under the central government and autonomous regions of China from 2009 to 2019 as research samples to study the influence of innovation capacity on industrial structure. The research results show that the influence of innovation capacity on industrial structure is in an inverted "U" shape, and the current innovation development is in the stage of inhibiting the development of industrial structure, but with the continuous improvement of innovation capacity, the subsequent development of industrial structure will be promoted. The size of the government and the economy of developed regions have a positive effect on the development of industrial structure, while the increase of urbanization level has an inhibiting effect on the development of industrial structure. Therefore, each region should continuously increase innovation investment and promote the combination of industry, academia and research, so as to promote the upgrading and development of industrial structure.*

Keywords: *innovation capacity, industrial structure, entropy method*

1. Introduction

The Interim Provisions for Promoting Industrial Structure Adjustment (Guo Fa [2021] No. 49) issued by the Central Committee of the Communist Organization of China and the State Council clearly states that promoting the optimization and upgrading of industrial structure, promoting the healthy and coordinated development of primary, secondary and tertiary industries, and gradually realizing sustainable development are important goals for the development of industrial structure in the current and future period. With the prevailing trend of reform, China's current industrial structure as a whole is developing toward a good trend, but the development of the tertiary industry still needs to be adjusted. There is an inextricable link between innovation ability and industrial structure adjustment, then, whether the influence of innovation ability on industrial structure is positively promoted or negatively inhibited, it needs to combine theory and empirical evidence for deeper research and analysis, which has certain practical guidance significance for the upgrading and development of industrial structure afterwards.

At the level of industrial structure, industrial structure upgrading is the process of shifting the center of gravity of industry from primary to secondary to tertiary, and the process of shifting the main composition of industry from labor-intensive to capital-intensive and finally to technology-intensive [1]. The research on industrial structure upgrading has been involved in many fields and has been developed quite maturely. Combining the economic progress of China for more than 40 years, it can be concluded that the optimization and upgrading of industrial structure can be broadly divided into two directions: highly [2] and rationalization [3]. The upgrading of industrial structure has a great role in promoting and enhancing the development of our national economy.

At the level of innovation capacity, innovation capacity refers to the capabilities related to the improvement of innovation level [4], which is the new driving force of high-quality economic development. Throughout the existing literature, along with the development of science and technology innovation, some scholars have researched on innovation capacity, and "innovation policy" and "innovation factors" have been taken as important indicators of human capital and urban development [5], and countries have also taken innovation capacity as one of the important indicators to promote the development of national economy.

The current research on innovation capability and industrial structure mainly focuses on the influence

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and effect of both on other factors. Scholars such as Liang Yijuan and Liu Zhuo have studied the influence of technology level and digital finance on industrial structure [6], and scholars such as Zhou Xia, Chen Yifan and Wang Wentong have studied the influence of intellectual property on industrial structure [7]. Although existing studies have summarized the impact of innovation capability on industrial structure and other aspect. However, few scholars have studied the non-linear relationship between innovation capability and industrial structure. On this basis, this paper conducts an in-depth study and analysis on the impact of innovation capability on industrial structure. The innovations of this paper are: First, the entropy method is used to calculate the industrial structure index, which takes into account several indicators and can better reflect the relationship between the two. Second, it empirically investigates the influence of innovation capability on industrial structure, and puts forward rationalized suggestions for promoting the upgrading and development of industrial structure.

2. Model

2.1 Entropy

In evaluating the industrial structure, this paper constructs the industrial structure index from three dimensions: advanced industrial structure, rationalized industrial structure and low carbon industrial structure, and uses the entropy value method to determine the weights of each index w_{ij}, whose weights are calculated based on the objective data of each index, with a certain degree of scientificity and objectivity. Before the construction of the system, it is necessary to standardize between each indicator to eliminate the difference in the scale, and the specific standardization process is as follows.

$$X_{ij} = \begin{cases} (X_{ij} - \min X_{ij}) / (\max X_{ij} - \min X_{ij}), X_{ij} \textit{ is the positive indicator} \\ (\max X_{ij} - X_{ij}) / (\max X_{ij} - \min X_{ij}), X_{ij} \textit{ is the negative indicator} \end{cases} \quad (1)$$

Where X_{ij} (i=1,2, ...m; j =1,2, ...n) represents the jth indicator of the ith province; the data used in the entropy method step are all standardized indicators, and the specific measurement steps are as follows.

(1) Normalized data for proportional transformation: $A_{ij} = X_{ij} / \sum_{i=1}^{n} X_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n)$.

(2) Calculate the entropy value: $h_j = -K \sum_{i=1}^{m} A_{ij} \ln A_{ij}$, where $K = 1 / \ln m$, when $A_{ij} = 0$, $A_{ij} \ln A_{ij} = 0$.

(3) Calculate the weights: $w_{ij} = (1 - h_j) / \sum_{j=1}^{m} (1 - h_j)$.

(4) Overall evaluation score: $T_{ij} = \sum_{j=1}^{n} X_{ij} w_{ij}$.

2.2 Tobit

The industrial structure index is between 0 and 1, which has the characteristic of being cut, and is eligible for the Tobit model setting of the restricted dependent variable; meanwhile, in view of the Tobit model being more used in the study of influencing factors, the following benchmark model is set.

$$\begin{cases} Y_{it}^{'} = \alpha_0 + \beta_k Z_{it} + \varepsilon_{it} \\ Y_{it}^{'} > 0, Y_{it} = Y_{it}^{'} \\ Y_{it}^{'} < 0, Y_{it} = 0 \\ i = 1, 2, ..., 30; t = 2009, 2010, ..., 2019 \end{cases} \quad (2)$$

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2.3 Variable

(1) Explained variable

The level of industrial structure upgrading is the explanatory variable of this paper, which is measured from three dimensions of industrial structure advanced, industrial structure rationalization and industrial structure low carbon respectively, and then the three indicators are synthesized by entropy value method. As Table 1.

Table 1: Index system of provincial industrial structure level in China

Target layer	Tier 1 Indicators	Secondary indicators	Indicator Type
Industry Structure Level	Advanced industrial structure (TS)	Ratio of tertiary sector output to secondary sector output	+
	Rationalization of industrial structure (TL)	Thiel Index	-
	Industrial Structure Decarbonization (TSL)	Ratio of total output value of tertiary and primary industries to GDP	+

The calculation of the advanced industrial structure (TS) is mainly based on the practice of Gan Chunhui, Zheng Ruogu and Yu Dianfan, and is measured by the ratio of the output value of the tertiary industry to the output value of the secondary industry [8]. The rationalization of industrial structure (TL) is expressed by the Thiel index, which is calculated by the formula: $TL = \sum_{i=1}^{n} (\frac{Y_i}{Y}) \ln(\frac{Y_i}{L_i} / \frac{Y}{L})$, where Y denotes the output value, L denotes the number of employments, i represents an industry, and n is 3 denotes the three major industries. Chen Fang and Zhang Shuqin point out that when $TL = 0$ indicates that the industrial structure of the region has not deviated and is in the most reasonable state [9]. The definition of low carbon industrial structure (TSI) is not clear. Many literatures mention that while maintaining the high speed of local economic development, the government increases the control on environmental protection, reduces the proportion of high carbon industries, and enterprises adopt more clean production technologies to achieve low carbon emissions and low carbon energy consumption in the production process, thus changing the industrial structure. In this paper, we use the sum of the output value of tertiary industry and primary industry to GDP ratio to measure the level of industrial structure decarbonization [10].

(2) Explanatory and control variables

The number of patents can directly reflect the overall innovation level, so this paper constructs the innovation capability index system from 2 levels: invention patents and utility patents [11].

It has been studied that FDI, government size, urbanization level, and economic level of different regions can affect the industrial structure, so these variables are selected as control variables in this study.

2.4 Data sources

Thirty provinces in China were selected as the sample to build the panel data from 2009-2019. The original data were obtained from China Statistical Yearbook, China Labor Statistical Yearbook, China Foreign Direct Investment Statistical Bulletin, and the databases of National Bureau of Statistics and China Economic Network, etc. The Tibet Autonomous Region was deleted due to serious data deficiencies. In this paper, the total foreign investment is converted according to the average exchange rate of RMB to USD for the year. Some indicator values are obtained based on quadratic calculations, and individual data of individual years are missing, which are handled by interpolation method.

3. Results

Tobit regression was performed on the industrial structure index and innovation capability, and the regression results are shown in Table 2.

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Table 2: Tobit regression results

variable	Tobit					
	UI	UI	UI	UI	UI (TOPSIS)	UI (TOPSIS)
	(1)	(2)	(3)	(4)	(5)	(6)
innovation	-0.0264***	-0.0314***	-0.0756***	-0.0538***	-0.0100***	-0.0086***
	(0.0084)	(0.0091)	(0.0258)	(0.0170)	(0.0010)	(0.0010)
innovation2	0.0023**	0.0027**	0.0222*	0.0099**	0.1075***	0.0917***
	(0.0010)	(0.0011)	(0.0127)	(0.0044)	(0.0082)	(0.0082)
FDI		0.0369	0.0513	0.0247		-0.0283
		(0.0686)	(0.0679)	(0.0702)		(0.0617)
govement		0.2998***	0.2899***	0.2920***		0.6086***
		(0.0867)	(0.0865)	(0.0869)		(0.0787)
urban		-0.1219**	-0.12631***	-0.1197**		-0.0812*
		(0.0476)	(0.0474)	(0.0479)		(0.0435)
area		0.0906**	0.0834**	0.0890**		0.0584*
		(0.0376)	(0.0379)	(0.0375)		(0.0310)
_cons	0.2579***	0.1189**	0.1237**	0.1197**	0.1339***	-0.0453
	(0.0317)	(0.0569)	(0.0575)	(0.0569)	(0.0263)	(0.0482)
sigma_u	0.1713***	0.1505***	0.1536***	0.1497***	0.1413***	0.1216***
	(0.0222)	(0.0196)	(0.0200)	(0.0195)	(0.0184)	(0.0160)
sigma_e	0.0402***	0.0392***	0.0392***	0.0393***	0.0392***	0.03195***
	(0.0016)	(0.0016)	(0.0016)	(0.0016)	(0.0016)	(0.0014)
LR	807.54***	735.86***	732.05***	731.16***	671.29***	655.27***

The relationship between innovation capability and industrial structure index is inverted "U", after adding variables, the influence of innovation capability on industrial structure does not change much and is still significant at 1% level. It shows that the innovation capability is in the process of inhibiting the development of industrial structure, and with the gradual increase of innovation capability, it will promote the development of industrial structure. This is because, at the beginning, the number of invention patents and utility patents is small due to the influence of national policies, science and technology, talents and other factors, but with the introduction of new technologies and talents, the number of invention patents and utility patents increases gradually, and the innovation ability gradually improves, which positively promotes the upgrading and development of industrial structure.

The effect of FDI on the industrial structure index is not significant because FDI tends to invest with short input cycle and long return time, and it does not produce significant promotion effect for the development of industrial structure.

Government size has a significant positive effect on the industrial structure index, indicating that the expansion of government size will promote the development of industrial structure. This is because the expansion of government size will help the expansion of capital and the introduction of talents to promote the development of industrial structure.

The level of urbanization has a significant negative relationship with the industrial structure index, indicating that an increase in the level of urbanization will inversely inhibit the development of the industrial structure. This is because the increase of urbanization level implies the increase of the number of populations gathering from towns to cities, and the increase of population is detrimental to the development of industrial structure under the normal development of industries.

The regional economic level also has a significant positive impact on the industrial structure index; economically developed regions are positively promoting the development of industrial structure, while economically backward regions are inhibiting the development of industrial structure. This is because the development of industry cannot be separated from the economy as the foundation, and the developed regional economy indicates that the region has made certain breakthroughs and progress in the economy and has a good foundation for industrial development, which can promote the development of industrial structure, while the economically backward regions, are not enough to support the long-term stable development of industrial structure.

To ensure the stability of the results, TOPSIS is used to calculate the industrial structure index again for regression analysis, and the test results are shown in columns (5) and (6), and the regression coefficients are in the same direction and significant at the 1% level, indicating that the results are robust.

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4. Conclusions

Under the economic background of China's reform and opening up that has always been adhered to for many years, the innovation ability has been continuously improved, regardless of the introduction of talents and economic development, which will certainly positively promote the development of further upgrading of the domestic industrial structure. In this regard, this paper constructs the industrial structure index from the three dimensions of advanced industrial structure, rationalized industrial structure and low carbon industrial structure, and then conducts Tobit analysis between the industrial structure index and innovation capability to study the influence of innovation capability on the industrial structure index, and draws the following conclusions: (1) innovation capability has an inverted "U (1) The innovation capacity has an inverted "U" shape on the industrial structure, which is currently in the process of inhibiting the development of the industrial structure, and then with the gradual improvement of the innovation capacity, the efficiency of the utilization of the innovation capacity will gradually increase in the future, which will promote the upgrading of the industrial structure. (2) Government scale and regional economic level have a significant positive effect on industrial structure. The expansion of government scale is conducive to the introduction of investment and talents, thus helping to promote the development and upgrading of industrial structure, while economic development can provide sufficient funds for the upgrading of industrial structure. (3) The level of urbanization has a significant negative effect on the industrial structure. The transfer of large numbers of population to cities puts certain pressure on industry and is not conducive to the further development and upgrading of industrial structure.

Based on the theoretical analysis and empirical results, this paper can draw the following policy insights: (1) Accelerate the accumulation of science and technology resources and establish innovation bases. The country needs to make efforts to accumulate its own science and technology resources and improve the efficiency of using them, so that independent R&D can be strengthened continuously and the overall innovation level can be enhanced. (2) Encourage the introduction of innovative talents. The introduction of talents plays an important role in the improvement of innovation capacity, which in turn introduces new talents and vitality for the development of industrial structure. (3) Optimize the economic market environment. In order to promote the sustainable and steady development of industrial development in the context of the economy, it is necessary to optimize the economic market environment, to rank the poor and retain the good, to find the key development direction and shortcomings, so as to promote the sustainable development of industrial structure. (4) Establish a sound industrial structure adjustment system, responding to the Interim Provisions for Promoting Industrial Structure Adjustment (Guo Fa [2021] No. 49) issued by the State Council, and establishing a sound industrial structure adjustment system, so as to promote the overall upgrading and development of industrial structure.

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