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An Empirical Analysis of the Relationship Between Innovation Input, Industrial Structure and Economic Growth

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Abstract. Economic growth is a dynamic category which reflects the changing direction and degree of the scale of social and economic activities. It is closely related to the innovation investment and industrial structure in a country. Based on the improved Cobb-Douglas production function, this author uses $LA-VAR$ econometric model to analyze the relationship between innovation input, industrial structure and economic growth, and conducts an empirical analysis of the panel data for 31 provinces, autonomous regions, and municipalities in China from 2007 to 2016. The empirical results show that there is a two-way Granger causality between innovation investment, industrial structure and economic growth, there is a one-way Granger causality between innovation input and industrial structure, and innovation input is the Granger cause of industrial structure.

Keywords: Innovation Input; Industrial Structure; Economic Growth; $LA-VAR$ Model.

1. Introduction

At present, economy in China is facing the pressure of downward growth and the requirement of structural adjustment. It is an inevitable choice for the economic development to implement the strategy of innovation driven development, improve the quality of economic growth and promote the optimization and upgrading of the industrial structure in China. To accelerate the formation of new ways for economic growth, it is a must to deal with the relationship between innovation input, industrial structure and economic growth. It is very important of how to promote transformation of industrial structure and achieve economic growth through innovation. Therefore, it is of great theoretical and practical significance to explore the relationship between innovation investment, industrial structure and economic growth.

The dynamic problem of economic growth has always been the concern of governments and academia. In the existing theoretical research, the relationship between innovation, industrial structure and economic growth mainly focuses on the relationship between innovation and economic growth, as well as the relationship between industrial structure and economic growth. In terms of research on the relationship between innovation and economic growth, many scholars have been guided by the theory of endogenous growth. They have analyzed the contribution of innovation to economic growth by means of Cobb Douglas production function, since the Austria economist Schumpeter put forward the theory of innovation in the early twentieth Century. AM Pece et al. (2015) used the multivariate regression model to analyze the effects of the potential for economic innovation on CEE national long-term economic growth, and proved the positive correlation between economic growth and innovation[1]; A Bara and C Mudzingiri (2016) established the causal relationship between financial innovation and economic growth in Zimbabwe, and found that the impact of financial innovation on economic growth depends on the measurement of the variations for financial innovation[2]; C Feki and S Mnif analyzed the relationship between entrepreneurship and economic growth. Their research shows that the short-term impact of technological innovation on economic growth is negative, while long-term effect is positive[3]; RP Pradhan et al. (2017) utilized $VECM$ model to evaluate the relationship between risk investment, innovation and economic growth, and found that risk investment and innovation activities contribute to the long-term economic growth per capita[4]. Since 1950s, scholars have deeply analyzed the relationship between industrial structure and economic growth, but scholars do not agree on the relationship between industrial structure and economic growth. Kuznets believed that the first is the growth of total amount, and then the change of industrial structure in the relationship between total and industrial structure change. On the basis of innovation, Rostow believed that some sectors with high innovation ability will take the lead in the economic development, which will lead to the transformation of industrial structure and the rapid development of economy through the related benefits from other sectors. Bo Zhang (2015) analyzed the impact of industrial structure on economic growth in Japan, and the empirical results show that the speed of adjustment of industrial structure has a positive role in promoting the economic growth[5]; Stojčić Nebojša eta al. (2016) investigated the relationship between economic structure and regional economic structure in the ten EU Member States after crisis, and distinguished the effects of economic structure in and intra-region[6]. X Li et al. (2017) compared different regions, and showed that the optimization of the industrial structure has obvious regional characteristics of impact on economic growth[7].

Through the combing of relevant literatures, it can be seen that the existing studies mainly focus on the research of the relationship between innovation, industrial structure and economic growth. The research on innovation, industrial structure and economic growth is less. The innovation of this paper lies in the study on the relationship between innovation, industrial structure and economic growth from the perspective of system instead of unilateral analysis of the relationship between innovation, industrial structure and economic growth. Therefore, on the basis of summarizing previous research results, this author uses the panel data of 31 provinces, autonomous regions, and municipalities in China from 2007 to 2016, applies $LA-VAR$ model to analyze the relationship between innovation input, industrial structure, and economic growth, and explores the optimal matching path of innovation-driven, industrial structure and economic growth, which is of great significance for China in formulating industrial restructuring and economic policies and promoting high-quality economic growth under the new normal.

2. Construction of the Model

This author first constructs a theoretical model between innovation input, industrial structure and economic growth, analyzes its mechanism of action, and then structures an econometric model.

2.1 The Construction of the Theoretical Model

The existing research shows that the economic growth is more consistent with the AK growth theory in China since the reform and opening up. When calculating the impact of input elements on economic growth, the Cobb Douglas production function is mostly adopted. The model is also used in this paper as follows.

$$Y = AK^{\alpha}L^{\beta} \tag{1}$$

In which, Y represents the total output, K is for the capital input, α for the output elasticity of capital input, L for the input of labor elements, β for the output elasticity of capital input, and A for the coefficient of scientific and technological progress, $\alpha+\beta=1$.

The two sides of formula (1) are divided by L. If $y=\frac{Y}{L}$ and $k=\frac{K}{L}$, formula (2) is obtained:

$$y = Ak^{a} \tag{2}$$

With the introduction of R&D input as a new production factor, the improved Cobb Douglas production function can be obtained.

$$y = Ak^{a}rd^{\gamma} \tag{3}$$

Among them, rd indicates the R&D capital investment, and γ for the output elasticity of R&D capital investment.

The logarithm of the both sides in formula (3) is taken, and the linear transformation can be obtained.

$$Lny = a + \alpha Lnk + \gamma Lnrd \tag{4}$$

2.2 The Construction of Measurement Model

The VAR econometric model is often used to analyze the relationship between economic variables in the existing research. Generally, it is divided into the causality test based on the horizontal VAR model and the causality test based on the difference VAR model. Some deficiencies exist in the causality test of multi variable system based on the former model, because the instability of variables and the integration of system variables are not taken into consideration. When the causality is tested, the relationship between stability and integration of variables is tested first based on VAR model, which is limited in the application of empirical test. A new test method is needed when the causality of the variables is paid attention instead of the integration of the variables. Toda and Yamamoto (1995) put forward the "causality test of $LA-VAR$ based on the extended VAR model", in which the number of unit roots and the integration of variables are not taken into account. The method based on the $LA-VAR$ model is as follows.

The following $VAR(L)$ process is supposed to be established and the optimal delay order L is assumed to be known.

$$Z_t = v + A_1 Z_{t-1} + \cdots + A_L Z_{t-L} + \varepsilon_t \tag{5}$$

Among them, Z_t, v and ε_t are the n-vectors, A_r is the $n \times n$-coefficient matrix when the lagged order is r, error term ε_t is an independent co distribution process with the error term of 0 mean.

Toda and Yamamoto suggest extra lag order d is added in the horizontal $VAR(L)$ model (d is for the largest single integer number of variables). The OLS method is used to estimate the $VAR(L+d)$ model and test the causality based on this model.

$$Z_t = v' + A_1' Z_{t-1} + \cdots + A_L' Z_{t-L} + \cdots + A_{L+d}' Z_{t-L-d} + \varepsilon_t' \tag{6}$$

Among them, v', A_1', $\cdots A_{L+d}'$ is the OLS estimation.

The $Wald$ coefficient is tested in formula (6). If the null hypothesis H_0 (H_0: the elements of line j and column k in A_r equal zero, $r = 1, \cdots L$) is not rejected, the k th element of Z_t is not the Granger cause of the j th element. The $VAR(L+d)$ model is used to test the causality, and generalized impulse response function can be obtained.

Specifically, $Z_t = (INNO_t, TS_t, RGDP)^T$ is set up, in which $INNO$, TS and $RGDP$ respectively indicate innovation investment, industrial structure and economic growth rate. Z_t may contain variables with different integer order (the highest is d). If Z_t is subject to $VAR(L)$, after the Granger causality is tested in the application of causality test based on the $LA-VAR$ model, the generalized impulse response function can be obtained in the variables of causal relationship according to the horizontal VAR model.

3. Selection and Calculation of Variables

3.1 The Selection and Measurement of Variables

3.1.1 Innovation Investment

Different scholars use different indicators to measure innovation input. Some adopt the number of patents to measure, based on the availability of data and other reasons, which has some limitations. Not every innovation can be applied and patented, and there is a difference between the quality of the patent and the actual economic value. Others use the sales revenue of new product to measure. This indicator cannot reflect the creation of knowledge in the process of innovation, but the practical application level of innovation. R&D investment is the direct factor of innovation and the most closely related index to innovation output. Therefore, considering the availability and comparability of data, this author adopts the intensity of R&D funding as a measurement index (INNO), that is, the ratio of R&D expenditure to GDP (gross domestic product).

3.1.2 Industrial Structure

Industrial structure refers to the composition, status and relationship of different industries in economy. It evolves with the growth of the economy, which is mainly manifested in the increasing proportion of the third industries. In order to reflect the change of the economic structure and draw lessons from Wu Jinglian and others, the author chooses the advanced industrial structure (TS) as an index to measure the industrial structure, that is, the ratio between the output value of the third industry and the second industry.

3.1.3 Economic Growth

Gross domestic product (GDP) reflects the total value of all the final products and services produced by a country or a region at a given time. In order to reflect the growth of the economy, the GDP growth rate (RGDP) is chosen as an indicator of economic growth.

3.2 The Data Sources

This author adopts the panel data of R&D investment intensity, second industry added value, third industry industrial added value and GDP in the 31 provinces, autonomous regions and municipalities in China from 2007 to 2016. The intensity of R&D funding comes from the 2007-2016 Year Statistics Bulletin of National Science and Technology Expenditure Statistics. The second industry added value, third industrial added value and gross domestic product come from the National Bureau of Statistics and the 2007-2016 National Economic and Social Development Statistical Bulletin.

4. Empirical Analysis

The model based on the $LA-VAR$ method is used to calculate the empirical data of the relationship between innovation investment, industrial structure and economic growth from 2007 to 2016. All of this analysis is done with Eviews7.0.

4.1 Determining the Best Delay Order

Before the horizontal VAR model is established, the lag order needs to be determined first. The method of determining the optimum lagging order is based on the larger lag order, and determined by the corresponding LR value, FPE value, AIC value, SC value, HQ value and so on. Considering the limitation of the sample interval, it is not suitable to choose a larger order from the maximum lag order, and select the best lag order $L = 3$ by 3 based on the LR value, FPE value, AIC value, SC value, HQ value and so on.

Table 1. The Test Results of the Best Lag Order for the Horizontal VAR Model

Lag Order	LR value	FPE value	AIC value	SC value	HQ value
0	NA	0.00	1.77	1.82	1.78
1	1989.84	0.00	-7.49	-7.30	-7.42
2	45.65	0.00	-7.63	-7.30	-7.49
3	56.94*	0.00*	-7.82*	-7.31*	-7.63*

Notes: "*" means that the lag order corresponding to the line where the marked value is located is the optimal lag order recommended by the test criteria corresponding to the column where the value is located. The five test criteria are: corrected LR detection statistics (5% levels), final prediction error (FPE), Akaike information content (AIC), Schwarz information content (SC) and Hannan-Quinn information content (HQ).

4.2 The Stability Test of the $VAR(3)$ Model

According to the stability test of Graph 1, all the roots of the $VAR(3)$ model fall within the unit circle, so the stability condition of the VAR model is satisfied, and the result of causality test and impulse response function is reliable.

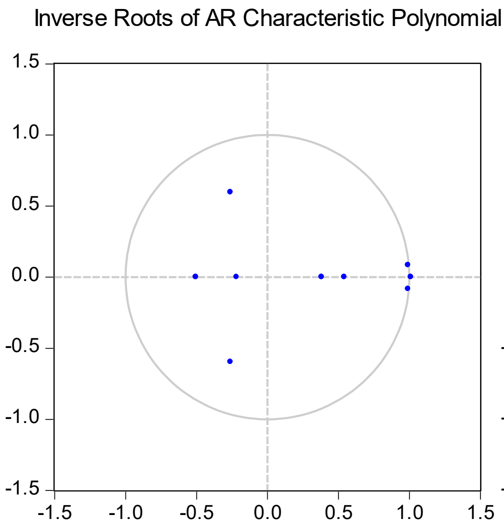

Fig. 1 The Stability Test of $VAR(3)$ Model

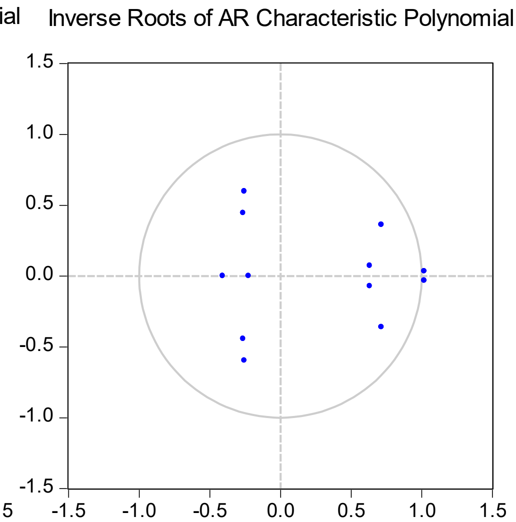

Fig. 2 Stability Test of $VAR(4)$ Model

4.3 The Causality Test based on $LA - VAR$

Before the impulse response function is obtained, the Granger causality between the variables is tested first, which requires the determination of the maximum integer order d of the 3-variable system. Previous studies have shown that most of the macroeconomic variables are $I(0)$ or $I(1)$ processes, that is, the variables are stable or contain up to 1-unit root. This is a reasonable assumption for annual data in this paper. According to the stability test of Graph 2, all the roots of $VAR(4)$ fall in the unit circle to meet the stability conditions and can be tested for cause and effect. The specific results of the Granger causality test are shown in Table 2.

According to the test results of Table 2, the causal relationship is analyzed between the innovation investment, industrial structure and economic growth in China as follows:

(1) Economic growth and industrial structure: When the three-variable system of innovation input is introduced, there is a two-way Granger causality between economic growth and industrial structure. Economic growth is the Granger cause of industrial structure, and industrial structure is the Granger cause of economic growth.

(2) Economic growth and innovation investment: There are a two-way Granger causality between the economic growth and innovation input. Economic growth is the Granger cause of innovation input, and innovation input is the Granger cause of economic growth.

Table 2. The Causality Test Based on $VAR(4)$ Model

Null Hypothesis	χ^2 Value	P Value	Conclusion
TS is not a Granger reason for RGDP	7.42	0.04	Rejection
R&D is not a Granger reason for RGDP	22.65	0.00	Rejection
RGDP is not a Granger reason for TS	31.98	0.00	Rejection
R&D is not a Granger reason for TS	15.96	0.00	Rejection
RGDP is not a Granger reason for R&D	11.67	0.01	Rejection
TS is not a Granger reason for R&D	4.57	0.20	Reception

(3) Industrial structure and innovation investment: There are a unidirectional Granger causality between the innovation input and industrial structure. Innovation investment is the Granger cause of industrial structure, and industrial structure is not the Granger cause of innovation input.

4.4 The Generalized Impulse Response Function

There is a direction and degree of the interaction between the variables of the causality in the study on generalized impulse response function. An impact on innovation investment and industrial structure can get the impulse response function of economic growth (see Graph 3). The horizontal axis indicates the number of lag periods of the impact, the longitudinal axis indicates the industrial structure and the creation input, and the solid line represents the impulse response function.

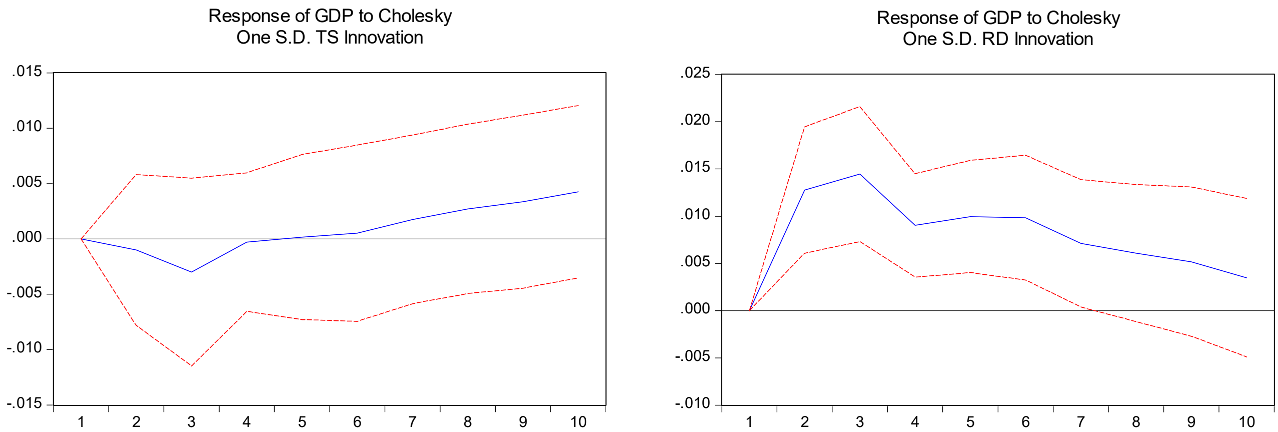

Fig. 3 The Function Curve of the Generalized Impulse Response Based on the $VAR(3)$ Model

From the graph, it can be seen that in the 1-4-year lag period, the impact effect of economic growth is negative after the impact of a unit on the standard deviation of the industrial structure; in the 4-10-year lag period, the impact effect is positive, which means in the long period, industrial structure has a certain role in promoting economic growth. The impact effect of economic growth is positive after the impact of a unit on the standard deviation from a unit of innovation, which lasts for a long time. This indicates that the positive impact of innovation investment enhances economic growth in a certain extent in a longer period.

5. Conclusion

In this paper, the $LA-VAR$ model is used to examine the relationship between innovation investment, industrial structure and economic growth in the 3-variable system, and the following conclusions are drawn.

Firstly, innovation investment has a positive impact on economic growth. Granger causality test shows that there is a bidirectional Granger causality between innovation input and economic growth. The results of generalized impulse response function show that both long-term and short-term innovation inputs have a certain role in promoting economic growth. This shows that innovation investment is the source of impetus for economic growth, and the increase of innovation investment is an important guarantee for sustained and healthy growth of economy. However, the current economic growth has not led to high growth in the intensity of innovation. Therefore, the innovation driven development strategy should be implemented, the incentive mechanism innovation and policy guidance should be established, the innovation strength should be improved constantly, the innovation system combining production, learning and research should be formed, the driving effect of innovation on economic growth should be exerted, and a two-way linkage mechanism of innovation investment and economic growth should be constructed.

Secondly, the level of industrial structure has a positive impact on economic growth. Granger causality test shows that there is bidirectional Granger causality between industrial structure and economic growth. The results of generalized impulse response function show that long term industrial structure plays a certain role in promoting economic growth. The higher the level of the industrial structure is, the higher the economic growth rate is. Therefore, in the process of promoting economic growth, the industrial structure should be further optimized, the development level of the third industry should be improved, the effect of the third industry on economic growth should be given full play, and sustained economic growth should be ensured and the quality of growth should be improved.

Thirdly, there is a one-way impact between innovation investment and industrial structure. The Granger causality test shows that the innovation investment is the Granger cause of the industrial structure, and the industrial structure is not the Granger cause of the innovation investment. Innovation should be the help of the optimization of industrial structure, and there is a necessary relationship between the adjustment of economic structure and the adjustment of the economic structure. However, there is a low innovation investment in China, and there is a huge difference between the region and the industry. This unreasonable structure of innovation input leads to the slow adjustment of industrial structure. Therefore, the capability of independent innovation should be improved, incentive policies for innovation investment should be formulated, investment in the third industry should be increased, and a reasonable investment and financing system should be established, so as to form a benign interaction mechanism between innovation input, industrial structure optimization and economic growth.

Generally speaking, there is no linkage mechanism between the innovation input, industrial structure and economic growth in China, which has affected the implementation effect of the innovation driven development strategy. Therefore, an incentive mechanism for innovation should be established, the investment in the third industry should be increased, and the driving role of innovation in economic growth and industrial restructuring should be brought into play, in order to form a linkage mechanism of reasonable growth of innovation investment, advanced development of industrial structure and economic development with high quality.

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