Dynamic Correlation Analysis of Construction Industry Development Level and Science and Technology Innovation

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Abstract. This paper analyzes the relationship between the technological innovation of the construction industry and the development level of the construction industry from the perspective of input and output in the construction industry. Using the time series data from 1995-2017, a vector autoregressive (VAR) model was established. The article uses co-integration analysis, Granger causality test, impulse response function and variance decomposition method to study the index variables. The long-term equilibrium relationship and short-term fluctuation effects between China's construction industry development, construction industry science and technology innovation investment and output are analyzed. The results show: there are long-term equilibrium relationships and one-way causal relationships between the three variables, and there is time lag. The output of science and technology innovation in the construction industry is positively responded to itself, the development level of the construction industry and the investment in science and technology innovation in the construction industry. Among them, it is most affected by the fluctuation of investment in science and technology innovation. Compared with the development level of the construction industry, the contribution of scientific and technological innovation to the output of scientific and technological innovation is even greater. Finally, relevant policy recommendations for the development of the construction industry and technological innovation in the construction industry are given.

1. Introduction

In the "Opinions of the General Office of the State Council on Promoting the Sustainable and Healthy Development of the Construction Industry" issued by the State Council in 2017, it clearly stated the objectives and tasks of "promoting the modernization of the construction industry and strengthening the application of technology research and development". It shows that the technological innovation capability and industrial technology advancement of the construction industry play a vital role in the sustainable and healthy development of China's construction industry.

The construction industry is the pillar industry of China's national economy and plays a very important role in China's economic growth. Therefore, many scholars have conducted many in-depth studies on the development of the construction industry. Yang Deqin et al. [1]studied the way of economic growth in China's construction industry. Xue Guohua et al.[2]studied the contribution of scientific and technological progress to the growth of the construction industry. Wang Kuotian et al.[3]analyzed the contribution of technological progress to the economic growth of the construction industry. Jiang Min et al.[4]empirically analyzed the relationship between the construction industry and the growth of the national economy. The results show that there is a cointegration relationship between the two variables; in the short term, the national economy is the cause of the growth of the construction...
industry; in the long run, the construction industry is the cause of the growth of the national economy. Wang Chuan et al.[5] also used the VEC model to study the relationship between investment in construction industry and economic growth. The results show that there is a two-way causal relationship between the two variables. Li Xianguang et al.[6] analyzed the influencing factors of the economic growth of the construction industry. The production function model is used to empirically study the three factors of capital investment, labor input and technological progress, and the contribution rate of each factor is obtained. Ke Yanyan et al.[7] used the Cobb-Douglas production function model and gray correlation model to analyze the impact of China's construction industry technology investment on the industry economy, and established a distribution lag model for lag analysis, and obtained the construction industry technology investment and industry economic development. The correlation is not significant, and there is a lag effect in the construction industry's technology investment. Shang Mei et al.[8] studied the influencing factors of technological innovation in China's construction industry, analyzed regional differences in technological innovation, and gave corresponding conclusions. Based on the literature research, scholars have studied the development level, economic growth, technical efficiency and technological progress of the construction industry from different perspectives. However, there are still vacancies in the research on the level of technological innovation in the construction industry. The academic community has not studied the relationship between the level of development of the construction industry and the level of technological innovation in the construction industry. For research methods, scholars mostly use production function models or DEA models to study economic growth and technical efficiency. Few scholars use vector autoregressive models to explore the dynamic correlation between variables. Therefore, this paper selects the data from 1995 to 2017 and uses the vector autoregressive (VAR) model to study the dynamic relationship between the development level of the construction industry and technological innovation.

2. Selection of research variables and data sources

2.1. Research variable indicator selection
This paper mainly studies the relationship between the development level of the construction industry and the level of technological innovation in the construction industry. Through studying the literature, it is found that scholars mainly use the total output value of the construction industry[4] or the added value of the construction industry[8] as a representative variable. Regarding the measurement indicators of scientific and technological innovation level, Huang Huiying et al.[9] measured the input and output of science and technology. The input was mainly for science and technology innovation funds, the growth rate of scientific and technological personnel, and the full-time equivalent of scientific and technological innovation personnel. The output was mainly the number of patent application authorizations and Number of papers published. Yang Fengqi et al.[10] used scientific and technological input to replace technological innovation. Ke Yanyan et al.[7] quantified the investment in construction industry technology into three indicators: R&D expenditure, scientific and technological personnel input and technical equipment rate. Wu Tongyu et al.[11] used the number of patents granted by the logistics industry to measure the level of innovation in logistics technology. Shang Mei et al.[8] used the number of patent applications per capita to characterize the level of technological innovation in the construction industry. Griliches[12] believes that there are certain limitations in patent measurement innovation, but there is still a very important relationship between the two. Under normal circumstances, the patent authorization standard is not easy to change. Therefore, it is feasible to use patent data to measure innovation. In addition, Cui Xinsheng[13] conducted a literature study on the technological progress and economic growth of patent characterization, pointing out that the use of patent measurement as an indicator of measurement technology advancement or innovation has been widely used by scholars at home and abroad.

In summary, the final selection of variable indicators in this paper is as follows:(1) Measuring the development level of the construction industry by the total output value of the construction industry, expressed by GOVCI; (2) Using the input and output of science and technology innovation in the
construction industry to jointly measure the level of technological innovation. Measuring the technological innovation output of the construction industry with the number of invention patents granted by the State Intellectual Property Office, expressed by NOPIA; Measuring the technological innovation investment of the construction industry with the rate of construction technology and equipment, expressed by RTECI.

2.2. Research data source

This paper uses three data of China's construction industry total output value, patent grant number and technical equipment rate as data estimation model. Data from the China Statistical Yearbook and the State Intellectual Property Office. Based on the accuracy, continuity and availability of the data, annual data from 1995 to 2017 were selected for empirical research.

In general, to eliminate the heteroscedasticity of time series data in order to linearize the trend of variables. By convention, the natural logarithm of the variable is taken.

3. Unit root test (ADF) sequence stationarity

When building a VAR model for estimation, the stability of the variables ensures the reliability of the model. Therefore, this paper uses the unit root test method to test LnGOVCI, LnRETCI, LnNOPIA. The test results are shown in Table 1 below:

| variable     | ADF test statistic | Inspection type (c, t, k) | Prob.  | conclusion |
|--------------|--------------------|---------------------------|--------|------------|
| LnGOVCI      | -1.661154          | (c, t, 2)                 | 0.7322 | unstable   |
| LnRETCI      | -0.521443          | (c, t, 2)                 | 0.9740 | unstable   |
| LnNOPIA      | -2.442997          | (c, t, 2)                 | 0.3498 | unstable   |
| DLnGOVCI     | -3.462705          | (c, t, 2)                 | 0.0699 | stable     |
| DLnRETCI     | -3.831779          | (c, t, 2)                 | 0.0351 | stable     |
| DLnNOPIA     | -4.047150          | (c, t, 2)                 | 0.0231 | stable     |

As can be seen from Table 1, the first-order difference of the three variables of the unit root test is stable at the 10% significance level, and the variables LnGOVCI, LnRETCI, and LnNOPIA are the first-order single-time series I(1).

4. VAR model lag order and Johansen cointegration test

The actual lag order of the VAR model is unknown, and the choice of the lag order affects the parameter estimation of the VAR model. Therefore, the optimal lag order of the VAR model needs to be determined before the impulse response analysis and variance decomposition. According to the research by Sims and Toda, the method of determining the optimal lag order of the VAR model starts from general to special from a large lag order. It is determined by the corresponding LR value, FPE value, AIC value, SC value, HQ value, and the like.

Table 2. Optimal lag period test results for VAR models.

| Lag | LogL   | LR   | EPE  | AIC  | SC   | HQ    |
|-----|--------|------|------|------|------|-------|
| 0   | -15.78302 | NA   | 0.001313 | 1.878302 | 2.027662 | 1.907459 |
| 1   | 70.57696  | 138.1760 | 5.83e-07  | -5.857696 | -5.260257 | -5.741070 |
| 2   | 85.39721  | 19.26633* | 3.52e-07  | -6.439721  | -5.394203* | -6.235625 |
| 3   | 96.98262  | 11.58540 | 3.33e-07* | -6.698262* | -5.204663 | -6.406696* |

Note: * indicates the lag sequence selected by the criteria.

Table 2 shows the detection results when the lag order is L=3. It can be seen from Table 2 that the SC value is the smallest when p=2, and the AIC value is the smallest when p=3. The results are contradictory, so the p-value can only be determined by the likelihood ratio LR. Therefore, the optimal lag order is chosen to be p=2, and the VAR(2) model is established. For the VAR(2) model, the stationarity test is carried out, and the reciprocal of the eigenvalue is within the unit circle (Figure. 1). Therefore, the VAR(2) model system is stable and satisfies the stationary condition.
It is known that the three variables of science and technology innovation investment, science and technology innovation output and construction industry total output value of the construction industry are the first-order single-time series, so it is necessary to prove whether there is a long-term stable equilibrium relationship between variables. The Johansen Cointegration Test is performed on the variables to determine the long-term equilibrium relationship between the variables. Cointegration test is performed using the initial default constant term of the system and the time trend term. The results are shown in Table 3 below.

### Table 3. Johansen Cointegration Test results (when the lag order is p=2).

| Hypothesized No. of CE(s) | Eigenvalue | Trace | 5% Critical Value | Prob. | Max-Eigen | 5% Critical Value | Prob. |
|---------------------------|------------|-------|-------------------|-------|------------|-------------------|-------|
| None*                     | 0.801049   | 55.25040 | 29.79707          | 0.0000 | 32.29395   | 21.13162          | 0.0009 |
| At most 1*                | 0.612313   | 22.95645 | 15.49471          | 0.0031 | 18.95112   | 14.26460          | 0.0084 |
| At most 2*                | 0.181487   | 4.005330 | 3.841466          | 0.0453 | 4.005330   | 3.841466          | 0.0453 |

Note: * indicates rejection of the null hypothesis at 5% significance level.

When the cointegration test takes the 5% threshold as the criterion, as shown in Table 3, the trace statistic is 55.25040>29.79707, rejecting the null hypothesis, indicating that there is at least one cointegration relationship between the above three variables; 22.95645>15.4947, rejecting the null hypothesis, indicating that there is at most one cointegration variable; 4.005330>3.841466, rejecting the null hypothesis, indicating that there are at least two cointegration variables. Similarly, according to the maximum eigenvalue statistics, the same result can be obtained. Therefore, from the long-term trend, there is a long-term stable equilibrium relationship between the three variables.

### 5. Granger Causality Test

The Johansen cointegration test shows that there is a long-term stable equilibrium relationship among the three variables, but whether the causal relationship is formed requires further Granger causality test. The results are shown in Table 4.

### Table 4. Granger Causality Test results.

| Null Hypothesis                  | p=2             | F-Statistic | Prob. | Conclusion |
|----------------------------------|-----------------|-------------|-------|------------|
| LnRETCI does not Granger Cause LnGOVCI | 4.72163 | 0.0245     | Refuse |
| LnGOVCI does not Granger Cause LnRETCI  | 1.07890 | 0.3635     | Accept |
| LnNOPIA does not Granger Cause LnGOVCI | 1.27825 | 0.3055     | Accept |
| LnGOVCI does not Granger Cause LnNOPIA  | 8.30238 | 0.0034     | Refuse |
| LnNOPIA does not Granger Cause LnRETCI  | 0.28474 | 0.7559     | Accept |
| LnRETCI does not Granger Cause LnNOPIA  | 0.37723 | 0.6917     | Accept |

Note: p is the lag period.
As can be seen from Table 4, in the case of a saliency level of 5%, the total output value of the construction industry is the Granger reason for the number of patents granted in the construction industry, but it is not the Granger reason for the technical equipment rate; the technical equipment rate is the Granger reason for the total output value of the construction industry, and the number of patents granted in the construction industry is not the Granger reason for the total output value of the construction industry; there is no Granger reason for the number of construction patents granted and the technical equipment rate. This shows that the investment of science and technology innovation in the construction industry is a one-way Granger cause of the total output value of the construction industry, and the total output value of the construction industry is a one-way Granger reason for the technological innovation output of the construction industry.

It can be seen that between 1995 and 2017, the technological innovation output of the construction industry is not the cause of the development of the construction industry, but the development of the construction industry is one of the reasons for the technological innovation output of the construction industry. The development of the construction industry is not the reason for the investment in science and technology innovation in the construction industry, but the investment in science and technology innovation in the construction industry is one of the reasons for the development of the construction industry. Therefore, there is a significant one-way causal relationship between the investment in science and technology innovation in the construction industry, the development level of the construction industry and the technological innovation output of the construction industry.

6. Analysis of Impulse Response Function and Variance Decomposition Based on VAR Model

6.1. Impulse response function analysis

The impulse response function is used to analyze the impact of the total output value of China's construction industry and the input and output of scientific and technological innovation, and the dynamic influence relationship between variables is studied in turn. The lag period is chosen to be 10, and the impulse response function graph of the next variable in the 95% confidence interval is obtained, as shown in Figure 2.

![Figure 2. Impulse response function curve.](image-url)
the technological innovation output of the construction industry on the development level of the construction industry and the output of technological innovation, and so on. As can be seen from Figure 2: (1) After the positive impact of the number of patents granted to the construction industry (LNNOPIA) in the current period, the total output value of the construction industry was in a stable state before the second phase. From the second phase to the sixth phase, the output value grew slowly, and the sixth phase began to increase significantly. The technical equipment rate variable first increased from the first period to the second period, and the second period to the fourth period decreased. After the fourth period, the growth continued, and the variable fluctuation range was large. (2) After a positive impact on the construction industry technical equipment rate (LNRETCI) in the current period, the construction industry's total output value increased slowly in the first three periods, the fourth to sixth periods were relatively stable, and the sixth period began to decline slowly. The construction industry patent authorization variable showed a growth state from the second period to the fourth period, the fourth period began to decline gradually, and the ninth period tended to be stable. (3) After a positive impact on the total output value of the construction industry (LNGOVCI) in this period, the technical equipment rate of the construction industry is in a continuous and relatively large growth state. The construction industry patent authorization variable began to show a slow growth trend in the second period, and began to stabilize after the eighth period.

6.2 Variance Decomposition analysis

Table 5: Variance Decomposition of LNNOPIA results

| Period | S.E. | LNNOPIA | LNRETCI | LNGOVCI |
|--------|------|---------|---------|---------|
| 1      | 0.127567 | 100.0000 | 0.000000 | 0.000000 |
| 2      | 0.149300 | 95.82608 | 2.714104 | 1.459814 |
| 3      | 0.152701 | 92.11468 | 3.224254 | 4.661070 |
| 4      | 0.164781 | 80.25072 | 5.915321 | 13.83396 |
| 5      | 0.178090 | 71.44195 | 5.443070 | 23.11498 |
| 6      | 0.194008 | 62.63752 | 6.500937 | 30.86155 |
| 7      | 0.219412 | 50.31749 | 15.14908 | 34.53343 |
| 8      | 0.256546 | 37.43463 | 28.51777 | 34.04760 |
| 9      | 0.301286 | 27.48668 | 40.55574 | 31.95757 |
| 10     | 0.348188 | 20.83559 | 49.17972 | 29.98469 |
| 11     | 0.393687 | 16.53264 | 54.93006 | 28.53730 |
| 12     | 0.436213 | 13.69655 | 58.78682 | 27.51664 |
| 13     | 0.475361 | 11.75373 | 61.49303 | 26.75324 |
| 14     | 0.511196 | 10.36335 | 63.50931 | 26.12734 |
| 15     | 0.543880 | 9.327895 | 65.09505 | 25.57705 |
| 16     | 0.573531 | 8.533007 | 66.38784 | 25.07915 |
| 17     | 0.600211 | 7.910748 | 67.45995 | 24.62930 |
| 18     | 0.623969 | 7.418369 | 68.35287 | 24.22877 |
| 19     | 0.644881 | 7.026737 | 69.09535 | 23.87791 |
| 20     | 0.663072 | 6.714479 | 69.71112 | 23.57440 |

Variance decomposition can realize the dynamic characteristics of the VAR(2) model. Decompose the mean square error of each variable in the model system into the degree of influence of each variable in the system, thereby discriminating the degree of influence of each variable. And calculate the contribution rate of each variable. It can be seen from Table 5 that in LNNOPIA's prediction mean square error decomposition, in the short term, the number of construction industry patent grants increases, and its own change is the most important contributor. However, in the long run, the contribution rate of the construction industry's technical equipment rate is gradually increasing, from 2.71% in the second year to 69.71% in the 20th year. The contribution rate of the total output value of the construction industry increased from 1.45% in the second year to 34.04% in the eighth year, and it has dropped from year to year to 23.57% in the 20th year. The total output value of the construction industry and the investment in science and technology innovation in the construction industry have a greater impact on the scientific and technological innovation output of the construction industry. It
shows that the improvement of China's construction industry's scientific and technological innovation output depends on the joint effect of scientific and technological innovation investment and industry development level. Comparing the contribution of the two variables to the output of science and technology innovation, the impact of the investment in science and technology innovation is far stronger than the impact of the development level of the construction industry, and this effect is long-term.

7. Conclusions and Recommendations

7.1. Conclusions

(1) From the perspective of long-term trends, there is a long-term cointegration relationship between the development level of the construction industry and the input and output of technological innovation. The Granger causality test shows that there is a significant one-way causal relationship between the development level of the construction industry, the investment in science and technology innovation in the construction industry and the technological innovation output of the construction industry. The investment of science and technology innovation can effectively promote the development of the construction industry. The development of the construction industry provides a good development environment for technological innovation, and thus can further promote the output of scientific and technological innovation. Combined with the actual research, it is found that the development level of the construction industry plays a vital role in the technological innovation of the construction industry. The development of the construction industry provides the necessary material foundation and good development conditions for scientific and technological innovation, and is a powerful guarantee and an important source for promoting the effective output of scientific and technological innovation in the construction industry.

(2) According to the impulse response function, the output of science and technology innovation in the construction industry is affected by the development level of the construction industry, and there is a lag effect. As time increases, its influence increases. It shows that the good environment provided by the development of the construction industry has a great impact on its technological innovation output. The investment in science and technology innovation in the construction industry also affects the effects of technological innovation output. The better the development of the construction industry, the greater the investment in science and technology innovation, and thus the promotion of technological innovation. It shows that the output of science and technology innovation is not only related to the degree of investment in science and technology innovation, but also related to the good environment in which it is located. In general, the development level of the construction industry and the investment in science and technology innovation have a positive effect on the output of science and technology innovation. This role has a certain lag, but in the long run, the intensity of the effect is gradually increasing.

(3) According to the contribution ratio shown by the variance decomposition table, the contribution rate of the technological innovation investment and construction industry in the construction industry to the variance of the technological innovation output of the construction industry is gradually increasing. And the contribution rate of science and technology innovation investment in construction industry to the growth of science and technology innovation output in construction industry is far greater than the growth brought by the development of construction industry. It shows that there is still room for improvement in the development of China's construction industry and the investment in science and technology in the construction industry. In the long run, compared with the contribution rate of the development level of the construction industry, the investment in science and technology innovation in the construction industry has a greater impact on the output of technological innovation. Therefore, the investment in science and technology innovation in the construction industry as one of the prerequisites for the output of science and technology innovation has a relatively important impact on the growth of scientific and technological innovation output.
7.2. Recommendations
Based on the above conclusions, in order to better promote the development level of China's construction industry and the ability of scientific and technological innovation, combined with the development characteristics of China's construction industry, the following suggestions are proposed:

1) Due to the short-term development of the construction industry and the impact of investment in science and technology innovation in the construction industry on the output of science and technology innovation, if the lag period can be shortened, it can help to increase the output of technological innovation. At this stage of China's construction transition period, the government is vigorously promoting the development of fabricated buildings, so that the rate of technical equipment has been improved, which effectively promotes the investment in scientific and technological innovation. When formulating development goals, the government must not only pay attention to short-term goals but also pay attention to long-term industry development goals.

2) There is a lag in the impact of the development level of the construction industry and the investment in science and technology innovation on the output of science and technology innovation. In the short term, it is difficult to give full play to the positive effects of the two on the output of science and technology innovation, and the expected results cannot be achieved. Therefore, it is necessary to make effective use of existing institutional mechanisms. According to the development requirements of science and technology innovation in the construction industry, the main body is guided to accelerate the construction of scientific and technological innovation systems and mechanisms to release vitality for the technological innovation of the construction industry. Provide strong support and guidance for the scientific and technological innovation of the construction industry, promote information sharing, technology research and development, standard setting, talent training incentive mechanism and technology promotion in the construction industry, and create a new mechanism to effectively guide, support and promote the technological innovation of the construction industry.

3) From the perspective of the long-term relationship between the development level of construction industry, the investment in science and technology innovation and the output of science and technology innovation, we should pay attention to the long-term impact of the continuous investment in science and technology innovation in the construction industry, and continue to increase the investment in science and technology innovation in the construction industry. Further improve the development level of the construction industry, make the industry develop fast and well, provide a good environment for technological innovation, and help promote the output of scientific and technological innovation. On the one hand, the investment in science and technology innovation requires the government to give full play to its guiding role, through policy tilt, financial and financial policy support, etc., to stimulate the maximum use of social resources, increase investment in science and technology innovation, and form a coordinated growth mechanism for the investment in science and technology innovation in the whole society. On the other hand, the government can further increase preferential policies such as tax reductions and exemptions, and mobilize the enthusiasm of relevant enterprises to encourage them to increase investment in science and technology research and development.

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