

The Promotion of Scientific and Technological Innovation Capacity: A Path Analysis Based on PLS-SEM for Northeast China

Yanan Shen^{1,*}, Min Shi¹, Yuhan Wu¹

¹ Harbin University of commerce, Harbin, 150028, China

*Corresponding author. Email: shenyn315@163.com

ABSTRACT

In this paper, PLS-SEM is used to investigate the influence of the input level of science and technology resources, the intensity of scientific and technological activities and the environment of scientific and technological innovation on the ability of scientific and technological innovation, and deeply analyzes the reasons for the low ability of scientific and technological innovation in Northeast China, so as to provide a theoretical basis for the upgrading path of scientific and technological innovation in Northeast China. The results show that the input factors of science and technology resources in Northeast China hinder the improvement of regional science and technology innovation ability. The environmental factors of scientific and technological innovation not only play a positive role in improving the output capacity of scientific and technological innovation, but also indirectly have a positive impact on the ability of scientific and technological innovation through the intensity of scientific and technological activities and the input of scientific and technological resources. Policy recommendations: increase investment in science and technology resources, optimize the environment for scientific and technological innovation, and promote the transformation of scientific and technological innovation.

Keywords: Science and technology innovation, structural equation model, partial Least squares method, path analysis

1. INTRODUCTION

Scientific and technological innovation plays an essential role in China's economic transformations and some scholars regard that as an inevitable way to enhance the core competitiveness of a country or region. Through reforms, we terminated passively introduced western capital, system and technology in favor of ushering in initiatives exporting and fully implementing open strategies with the Belt and Road initiative. According to the relevant data in National Innovation Index Report 2016-2017 and China Regional Science and Technology Innovation Evaluation Report 2016-2017, the ability of China's comprehensive science and technology innovation ranks 17, which is in the upper and middle reaches of the world. The average level of the national comprehensive science and technology index is 67.57, which is 1.08 points higher than that of 2015-2016. Based on this index, 31 regions in China can be divided into three categories: first, the comprehensive index of scientific and technological innovation in Beijing, Shanghai, Tianjin, Guangdong, Jiangsu and other places in the eastern region is higher than the national average level; second, the index of Hubei, Chongqing, Shanxi, Shandong, Sichuan, Fujian, Liaoning, Heilongjiang, Jilin, Anhui, Hunan, Shanxi, Gansu and Jiangxi in the central and western regions is

lower than that of the whole country; the third category is the index below 50 points, including Hebei, Qinghai, Guizhou, Yunnan, Tibet, Henan, Ningxia, Inner Mongolia, Xinjiang, Guangxi and Hainan in the western region. These can be seen that the comprehensive scientific and technological innovation level of Liaoning, Jilin, Heilongjiang provinces are under the country's average level. As an important part of China's energy, industry and commodity grain bases, the economic situation of the three provinces in Northeast China is very severe. Its deep-seated characteristics are reflected in the gradually prominent problems of scientific and technological innovation.

The investment and patent counts are the crucial indicators to weigh out the capability of scientific and technological innovation in a country or a region. This paper analyzes the scientific and technological innovation in Northeast China from three aspects which are the scale of technological employees, the internal aggregate expenditure in R&D and the number of authorized patent applications. It indicates that the quantity of technological staffs is growing slowly and its proportion in whole country are declining year by year from 8% in 2019 to 6% in 2016, especially for Liaoning, constantly decreasing after a peak of 162625 in 2014. Simultaneously, the ratio of Northeastern R&D outlays in the whole nation come down every year, from 9% in 2002 to 4% in 2016. Thus it may be known, the funds of R&D are insufficient. Patent

applications weight is slowing rising year after year, while the proportion in the whole country is dwindling, from 8% (in 2002) to 3% (in 2016), which concludes that the ability of technological innovation need to further enhance. Thus, the intensified discussion and research on how to improve have momentous realistic meaning.

2. LITERATURE REVIEW

Scientific and technological innovation is a general term of original scientific research and creative technics. It refers to the process of creations, applying new knowledge and skills, adopting inventive production patterns and management modes, developing original products, making the quality of products even better and providing new services. Xuesen Qian, one of Chinese greatest scientists, propounded open complex giant system theory which divides scientific and technological innovation into some aspects of knowledge, techniques and technology-led management. And in this view, the academic circles mainly carry out studies in the following respects:

2.1. Research on the Relations between Science and Technological Innovation

Jun Liang[1] and others (2018) quantitatively analyzed connection between educational human capital and its spillover effect and capability of technological innovation, concluding that considering the spillover effect of human capital is 0.1415% higher than without taking that factor in account; Yinliang Xu (2018) deployed the extended DES evaluation method drew the conclusion that the efficiency of promoting technology innovation-driven industry is in coincidence with regional original ability and the level of economic development; Tinghui Li (2018), Tingting Xie (2017) and other scholars obtained the inverted U-shaped relationship theory between technological innovation mechanism and industrial structure, revealing the role of technological innovation in the optimization and adjustment of industrial structure. Qiuye Xu and others (2018) studied the coupling effect of scientific and technological innovation and new urbanization. The results show that in recent years, the coupling degree between the two gradually increases, and the R&D personnel investment has the most significant impact on the new urbanization. Thanks for their fruitful results, following scholars acquired a strongly supported theory to further advance studies.

2.2. Research on the Theory of Scientific and Technological Innovation

The research on the theory of scientific and technological innovation mainly were conducted on several aspects including the efficiency, the allocation of resources, the convergency and diffusion, mechanism, effect, capability

and so on. During the process of research, regional and human capital elements are the main segmentation criteria. Jitong Lu [2] (2016) established a complex system synergy degree model and a time series dynamic model to measure the spatial spillover effect, synergy effect and economic growth, and also built a long-term available mechanism for Beijing-Tianjin-Hebei regions. Based on the input-output theory Xiangai Tong [3] and others (2018) matured the comprehensive index of science and technology innovation, form the perspective overall score, to take an empirical study on the technological innovation ability of Guangzhou-Shenzhen in 2016, through constructing the evaluation index system of that capability. Zhigang Li [4] (2015) constructed DEA model using DEA- Malmquist index to dynamically analyze the innovation efficiency of technological human capital, and presented its improving mechanism through the angle of the human capital stocks, structure configuration and flows. Yuehua Peng [5] (2010) is grounded on talent theory, human capital theory and sci-tech administration theory to set up the evaluation index system of technological allocation of human resources and management, from respects of capabilities of technology innovation potentiality, technology development, technology output, technology contribution.

2.3. Research on the Ability of Scientific and Technological Innovation

In a different fashion, Minghai Yang and others [6] (2018) intensively discussed the regional disparity, spatial-temporal transfer, influencing factors and spatial spillover effects by utilizing Theil index, spatial Markov chain and spatial Durbin model, in China's eight comprehensive economic zones (except Hong Kong, Macao and Taiwan), which ameliorated the dynamic evolution trend of regional division of scientific and technological innovation ability. Nevertheless, most of existed research on scientific and technological innovation ability has been concentrated on comparative study and evaluation study but less of that on the path of improving.

On the basis of systematically combing the relevant literature, as far as quantitative analysis is concerned, this paper primarily conducts several studies as follows. First of all, we deeply probe into the capability of scientific and technological innovation and further calculate the paths to boost the ability of scientific and technological innovation in areas of Northeast China. Secondly, considering science and technology, talents and policies, the influencing factors of regional scientific and technological innovation ability are set as three respects which are the level of resources input, the activity intensity and innovative circumstance in science and technology. On top of that, using the output capability to evaluate the science and technology innovation capacity in Northeast China; PLS-SEM is used to quantitatively measure the specific influential path of each factor on the innovation capability of science and technology to establish PLS-SEM model and carrying out empirical research. At last, this paper

draws conclusions propounded suggestions to advance science and technology innovation in Northeast China.

3. MODELS, METHODS AND DATA

3.1. Index Selection and Date Source

China's scientific and technological innovation capability is affected by the indicators of scientific and technological innovation output and the input indicators of scientific and technological innovation. The output capacity of science and technology innovation is mainly quantified by four indicators: the number of patents, the number of papers, the number of high-tech products and the turnover of technology market. Adopting the basis of scientific and technological innovation, the industrial innovation environment, technology absorption capacity and education quality are quantified. The basis of scientific and technological innovation is to quantify the R&D personnel's full-time equivalent and R&D expenditure. The industrial innovation environment is generally quantified by the industrial geography concentration index, and the technical absorption capacity is quantified by relevant indicators such as FDI, international trade and technology import, and education funds for education quality. Quantify the indicators such as the proportion of GDP or government technology investment. On the basis of much previous research results, This paper filters the above indicators, and probe into the main factors of regional scientific and technological innovation ability from three aspects: the input level of resource, the activity intensity and the innovation circumstance in science and technology, and evaluate the scientific and technological innovation capability with the output capacity science and technology. According to system index to set up principles of systematicness, purposiveness and feasibility and structure evaluation index system of science and technology ability. Those three aspects mentioned above play major roles on the scientific and technological ability of output and innovation. Specifically, the input level of sci-tech resource includes human and financial resources, in here, using the total the number of R&D staff and the expenditure of R&D funds to measure them, separately; the intensity of technological activity consists of the technological associations' training and academic strength, and these are both quantified by the number of participants; the technological innovation circumstance comprised with the level of economic growth, educational potential, scientific and technological quality and regional competitiveness, which are weighed by gross local product, the number of students in colleges and universities, the stock of human capital and index of regional competitiveness, respectively; using the granted patent application counts and turnover volume of scientific and technological market to calculate patent output and the transformation of science and technology achievements.

The sample period of subjects in this study is from 2002 to 2016. The relevant observation of secondary index stem from China Statistical Yearbook (2001-2017), Heilongjiang Statistical Yearbook (2001-2017), Liaoning Statistical Yearbook (2001-2017), Jilin Statistical Yearbook (2001-2017), China Science and Technology Statistical Yearbook (2001-2017) and National Research Network Macroeconomic Database. In summing up the corresponding data of Heilongjiang, Jilin and Liaoning Provinces, we obtained eight index values, including the total number of R&D personnel, R&D expenditure, participants in technological training and academic activities, the gross of local products, the quantities of students in collage and universities, grand patent application counts and turnover of tech markets. The stock of human capital is acquired by using the method of average years of education. Adopting Maoxing Huang [7] proposed prediction model the competitiveness index- of comprehensive economy is obtained. And in term of missing data, this paper proceed with smoothing processing, according to data's variation tendency.

3.2. Basic Hypothesis

Dividing the factors affecting the ability of scientific and technological innovation into three dimensions: the input level of resource, the activity intensity and the innovation circumstance in science and technology; differentiating the evaluation of scientific and technological innovation ability as scientific and technological output capacity and technological innovation level. Based on above-mentioned analyses of variations and relations, the following hypothesis are given:

H1: The higher the input level of scientific and technological resources, the higher the capacity of scientific and technological output; H2: The higher the intensity of scientific and technological activities, the higher the capacity of scientific and technological output; H3: The better scientific and technological innovation circumstance, the higher output capacity of technology; H4: The better scientific and technological innovation circumstance, the higher the input level of scientific and technological resources; H5: The better scientific and technological innovation circumstance, the higher the intensity of scientific and technological activities.

3.3. PLS-SEM Model Construction

The structural equation model (SEM) includes two basic models: measurement model and structure model. Specifically, the measurement model is a linear function of a group of observation variables and comprised of potential variables (unobservable variables) and observation variables. The structure model is a causal model among potential variables, also known as causal model. The regression relationship is performed as merely existing measurement model without structure model

which called confirmatory factor analysis; conversely, it is equivalent to the traditional path analysis. As results of analyzing the above index system, this paper includes either the measurement model of confirmatory factor analysis and the structure model of causal analysis amongst potential variables to establish structural equation model. There are some commonly used software for structural equation models such as: AMOS, Smart-PLS, LISREL, etc. Specifically, the estimation method which LISREL and AMOS both applied is the maximum likelihood method that demands a higher quantity of sample size, generally, up at least 200. PLS-SEM model is a kind of structural path analysis model based on least squares analysis method. Considering that PLS-SEM model without any requirement on data's distribution is a comparatively ideal approach for path analysis even in the case of small sample size, it can objectively reflect the impact of various elements on ability of science and technology innovation. Therefore, this paper analyzes the path of boosting the regional scientific and technological innovation capacity in Northeast China, through constructing PLS-SEM model. The established PLS structure equation model is as below:

The relationship between potential and observed variables are given by:

$$\rho_i = \sum_{j=1}^n \lambda_{ij} \alpha_{ij} + \theta_i \tag{1}$$

where is denoted as potential , in this paper, it separately refers to resource input level , intensity of scientific and technological activities , science and technology innovation environment , science and technology innovation input ; represents observed variables, errors and corresponds to regression coefficient of on .

The connection between two potential variables, as follows:

$$\rho_i = \sum_{i \neq j} \beta_{ij} \rho_j + \varepsilon_i \tag{2}$$

Where and represent different latent variables, their path coefficient indicating the interrelation among them, and the error of model.

The parameter estimation method of the PLS structural equation model is to obtain the estimated value of the latent variable through iterative iteration.

In this paper, the partial least square method is used to analyze the established structural equation model. Next to construct path model diagram in which the ellipse shape represents the latent variables, the box-like shape shows observed variables, and the "z" in front of each observed variables indicates that the data was normalized. The concrete scheme of structural equation path analysis is as shown in Figure 1:

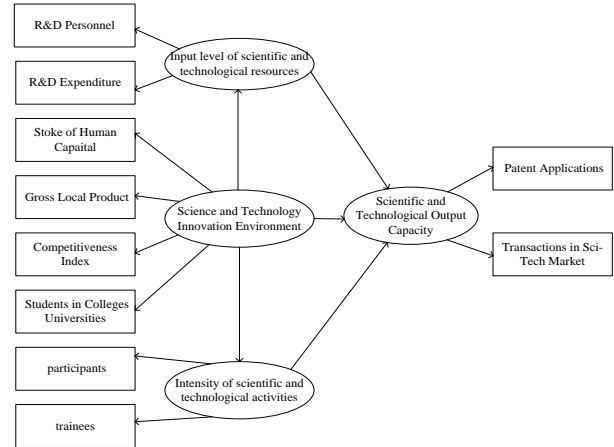


Figure 1 Structural equation path analysis chart for promoting science and technology innovation capability in northeast China

4. EMPIRICAL RESULT ANALYSIS

4.1. Model Checking

In this research, during the structural equation operating, the maximum number of iteration is limited to 300, the convergence criterion is 10⁻⁷ and the initialization weight is 1. Data's reliability and validity refer to data's consistent or stable degrees. As can be seen from chart 2, the data used in this study has already passed the test of data reliability Cronbachs Alpha value (threshold 0.7). And data validity has passed the examination of average extracted variation AVE value (threshold 0.5), and the operation result of structural equation presented steady.

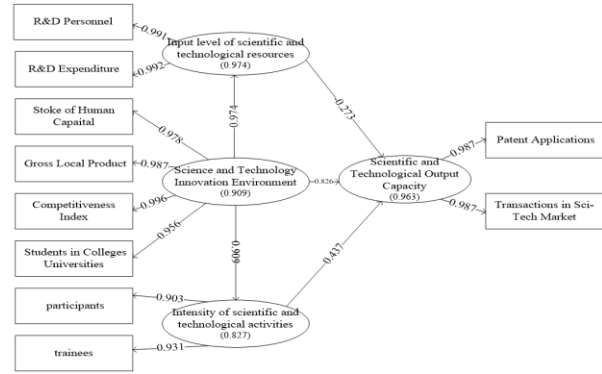
It can be seen: from the positive and negative of the path coefficient that the all potential variables of that have experienced change from negative to positive in 2002-2016; the four potential variable were all negative from 2002-2008; in 2009 and 2010 the scientific and technological resource input and circumstance of science and technology innovation separately first emerged positive 0.1 and 0.23; and then the scientific and technological input capacity, in 2011, showed positive 0.33. However, from the following table, it can be figure out that the technology input coefficient has decreased in 2014, 2015- 2016 almost unchanged; the intensity of scientific and technological activities notably increased from 2011 to 2012; after a decline in 2013 but slowly recovered; the scientific and technological input capability presented somehow reducing in 2012-2013 while sluggishly rose up again in nest year.

4.2. Path Coefficient Analysis of Time Series for Latent Variables of Technological Innovation Ability.

It can be seen: from the positive and negative of the path coefficient that the all potential variables of that have experienced change from negative to positive in 2002-2016; the four potential variable were all negative from 2002-2008; in 2009 and 2010 the scientific and technological resource input and circumstance of science and technology innovation separately first emerged positive 0.1 and 0.23; and then the scientific and technological input capacity ,in 2011, showed positive 0.33. However, from the following table, it can be figure out that the technology input coefficient has decreased in 2014, 2015- 2016 almost unchanged; the intensity of scientific and technological activities notably increased from 2011 to 2012; after a decline in 2013 but slowly recovered; the scientific and technological input capability presented somehow reducing in 2012-2013 while sluggishly rose up again in nest year.

4.3. Path Coefficient Analysis for Advancing Capability of Scientific and Technological Innovation Capability

According to the SmartPLS3.0 testing results(see Figure 2), from the positive and negative if the path coefficient, it can be found out that the path coefficient of scientific and technological resources input to innovation output is negative-0.273, indicating that the investment in science and technology resources has obstructed Northeastern region enhancing their ability of science and technology innovation. This result is basically coincident with our above analysis on current situation of three Northeast provinces. the intensity of scientific and technological activities and environment have a positive effects on output, respectively 0.437 and 0.826, which exposit that scientific and technological innovation circumstance have more powerful affect than activities intensity; the path coefficient of the scientific and technological innovation environment to resource input level and actives intensity are positive, separately 0.974 and 0.909. It can be concluded that, on the one hand, the present environment of scientific and technological innovation where Northeast region being is conducive to enhancing its activities intensity. On the other hand, we can figure out that the innovative circumstance is plays essential role in promoting input ability in the field of scientific and technological innovation for Northeast China.



Reference source: according smartPLS3.0 calculation result to collect and conclude.

Figure 2 Distribution of path coefficient of scientific and technological innovation capacity improvement in northeast China

5. CONCLUSION AND PROPOSAL

This paper divides the influencing factors of scientific and technological innovation ability into three dimensions: resources input level, activities intensity and innovation of science and technology. And we employ scientific and technological output ability to evaluate the innovation ability of Northeastern region. Then in order to empirically demonstrate the effective path for advancing the Northeastern region’s science and technology ability, we utilize PLS-SEM to quantitatively measure various factors which have specific impact on scientific an technological innovation capabilities. The research conclusions point out: there are some hindered function that the scientific and technological resource input, including human and finance resource, to innovation ability promoting in Northeast China. The intensity of scientific and technological innovation capability activities and the innovative environment have positively promoted the innovation ability, correspondingly, the scientific and technological innovation circumstance also plays the same role in resource input. The study conclusions of this paper present abundant realistic significance for further boosting the capabilities of science and technology innovation in Northeast China:

First of all, increase investment in science and technology resources. The research conclusions of this paper show that the investment in science and technology resources in Northeast China has hindered the improvement of regional scientific and technological innovation ability. The investment in science and technology resources is also discussed from the aspects of human resources and financial resources investment for increasing the investment in science and technology financial resources. According to the “Statistical Bulletin of National Science and Technology Funds in 2017”, among 31 autonomous regions, the total R&D expenditures in Liaoning provinces ranked 16, 21 in Heilongjiang, 24 in Jilin, and they all locate in middle and lower level in Northeast China. The

investment in science and technology resources in Northeast China needs to be increased. And these provinces demand to rise investment in human resources, continuously expand investment channels for human capital, adjust the investment structure of human capital. Secondly, optimize the environment for technological innovation. This paper indicate that the technological innovation environment not only directly affects the technological innovation output capability, but also indirectly affects the technological innovation capability through the intensity of activities and the resources input in science and technology. Further optimizing the technological innovation environment in Northeast China is an important guarantee for enhancing the ability of scientific and technological innovation. To optimize the allocation of R&D resources in the Northeast, further develop the government's management advantages for R&D, and augment the government's direct investment in scientific and technological innovation. In addition to boosting the research and development environment, it is also necessary to provide a good development platform to arouse the initiative of scientific and technological innovation, and to retain talents, consistently exerting the innovative potential they possessed

Thirdly, we require to promote the transformation of scientific and technological innovation achievements in Northeast China and transform technology into productivity. Specifically, there are several steps we should to implement: formulate targeted scientific and technological achievements transformation policies, create a service platform for effective transformation of scientific and technological achievements and a diversified capital chain, establish an effective incentive mechanism, accelerate constructing service system of scientific and technological innovation results. And strengthening the main body of enterprises in the transformation of scientific and technological innovation achievements is a powerful measure for promoting the achievements transformation of scientific and technological innovation in Northeast China.

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