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The Impact of R&D Investment on Industrial Enterprises' Technological Innovation Ability

—Based on Data from Ten Provinces and Cities on the Eastern Coast of China

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***Abstract*—Based on the current status of technological innovation ability of industrial enterprises in China, this work used Cobb Douglas production function to analyze the impact of R&D personnel investment, effective patent quantity and enterprise R&D expenditure on technological innovation ability of industrial enterprises. Then, this work used variable coefficient model of panel data to analyze differential impact of enterprise R&D investment on technological innovation ability. The research results show that the number of effective patents and R&D personnel have no significant impact on technological innovation ability, while the impact of enterprise R&D expenditure on technological innovation ability is positive, and areas with high input have low elasticity.**

Keywords—R&D investment; Technological innovation ability; Panel data

I. Introduction

As an irreplaceable part of the market economy, industrial enterprises play an important role in promoting national taxation, creating social wealth and providing employment. Industrial enterprises are not only developing rapidly in scale, but also paying more attention to the technological innovation ability, thus their R&D investment and output levels have made significant progress and improvement. However, due to the inherent shortage of funds, talents, informatization level and technology, the gap of industrial enterprises between China and developed countries is obvious, and the development of different regions in China is also extremely uneven. Therefore, it is necessary to improve the technological innovation ability of industrial enterprises, enhance their market competitiveness, and balance the development among regions.

There are many studies on the impact of R&D investment on the technological innovation ability of enterprises at home and abroad. Jamasb T and Pollitt MG believe that stimulating R&D investment cooperation network and intellectual property protection policies play a good guiding role in the technological innovation in the UK electricity and energy market [1]. Wen Yuchun believes that when industrial innovation is in an obvious market-oriented stage, enterprises should focus on introducing market-oriented independent research and technology if they want to obtain more new product market revenue [2].

Jefferson uses panel data of large and medium-sized manufacturing enterprises in China from 1997 to 1999 to construct a linear knowledge production function, and concludes that the ratio of R&D expenditure to sales revenue has a significant positive effect on new product sales revenue [3]. He Wei uses Cobb Douglas production function to analyze the data of China's large and medium-sized industrial enterprises from 1990 to 1999, and concludes that the lag period of technology development cost is about three years, and the output elasticity is between 0.35 and 0.44, showing the characteristics of large elasticity but poor persistence [4]. Some scholars have begun to pay attention to whether there is a threshold effect on R&D investment, so as to verify whether more R&D investment is better [5]. Based on calculating the R&D capital stock of large and medium-sized industrial enterprises in China from 1993 to 2002, Wu Yanbing constructs a knowledge production function, and concludes that R&D personnel has greater elasticity of output than capital, and the knowledge production process shows the characteristic of constant or decreasing return to scale. Characteristics [6]. Yu Liping uses the panel data variable coefficient model to analyze the data of China's high-tech industries in 30 provinces except Tibet from 2006 to 2010, and finds that the output elasticity of scientific research funds in the western region is greater than that in the eastern region [7].

From the above analysis, it can be found that there are many theoretical and empirical studies on the impact of enterprise R&D investment on technological innovation, but it still has following shortcomings: First, the existing research mainly focuses on the analysis of various provinces, regions or industries around China, but does not analyze the developed eastern coastal areas of industrial enterprises. Second, it does not pay attention to the impact difference of a certain R&D input factor on different regions. Finally, there is no specific division in R&D expenditure, or the scope is not comprehensive. In addition, analysis targets are mainly high-tech enterprises, but do not pay attention to the scientific and technological innovation activities of industrial enterprises, resulting in incomplete research results. Therefore, this work took industrial enterprises as the research subject, deeply researched on the relationship between R&D investment and technological innovation efficiency of industrial enterprises, and then analyzed the impact difference of a certain R&D input factor on the technological innovation efficiency of 10 provinces and cities in the east.

II. Economic Theory and Research Methods

In response to various problems existing in the process of innovation in industrial enterprises, all sectors of society, especially the academic community, are actively seeking ways to solve problems. This work researched on the impact of different R&D input factors on technological innovation ability in different regions and the impact difference of a certain R&D input factor on different regions over a period of time. Therefore, the methods to be applied are mainly panel data analysis and Cobb Douglas production function.

A. Panel data model

The panel data was first introduced by Mundlak into the econometric model, including several cross sections and bi-dimensional data within a certain time span. It can be divided into variable intercept model and variable coefficient model according to different assumptions of individual members and time series. Panel data variable coefficient model can be used for different individual structural parameters. This work used the variable coefficient model to study the impact difference of a certain R&D input factor on the innovation efficiency of industrial enterprises in different regions.

B. Cobb Douglas production function (also known as C-D production function)

The C-D production function is an important theoretical model for the study of knowledge production, technological innovation and their determinants. It combines innovation output and innovation input. It believes that R&D investment and human resource investment are the main inputs of knowledge production and innovation. The academic community generally expresses this production function as

$$Y_{it} = AK_{it}^{\alpha} L_{it}^{\beta} e_{it}$$

Y is the R&D output, K and L are the capital investment and R&D personnel input respectively, A is the technical innovation efficiency, α and β are the output elasticity of capital investment and R&D personnel input respectively, and e_{it} is the random error term.

Based on the C-D production function, this work added enterprise R&D expenditure, full-time equivalent of R&D personnel and the number of effective patents, and simplified the production function.

III. Establishing Models and Empirical Analysis

A. Selection of samples

This work chose 10 provinces and cities along the eastern coast as research perspectives. The reason for choosing this region is that the region is not only one of the areas with rapid economic development in China, but also a region where innovation activities are concentrated. This work selected 2011-2016 as research period, took 10 provinces and cities on the eastern coast as research sample, and took the R&D investment of industrial enterprises as foothold. Data used in the research comes from the 2011-2016 *China Statistical Yearbook on Science and Technology*, *China Statistical Yearbook* and statistical yearbooks of provinces and cities in the eastern coastal areas. Due to a large number of missing data in Hainai province, it is removed as an outlier.

B. Establishment of the model

This work divided the R&D investment into three aspects: the number of effective patents, the full-time equivalent of R&D personnel, and the investment in R&D of enterprises. This work selected the full-time equivalent of R&D personnel, which is more reasonable than using the number of researchers directly. This is because although some researchers are not full-time researchers, they will also have a certain impact on the innovation output of enterprises. The indicators of technological innovation ability mainly include new product sales revenue, new product output value and the number of patent applications. Technological innovation activities are different from general productive activities. They are creative production activities that generate new products and new processes, and at the same time face the market and make profits. In addition, new products produced may not be sold entirely. Therefore, this work adopted sales revenue of new products in the selection of technical innovation ability indicators. Taking into account the lag impact of R&D investment, a one-year lag period is used when setting up the model. In summary, combined with the Cobb Douglas production function, the model is set as follows:

$$REV_{i,t} = AJ_{i,t-1}^{\partial_1} P_{i,t-1}^{\partial_2} Z_{i,t-1}^{\partial_3}$$

REV is the sales revenue of new products, J, P and Z are enterprise funds in R&D investment, the full-time equivalent of R&D personnel and the number of effective patents, and A is the technological innovation ability, which is generally a constant term. In order to reduce heteroscedasticity and increase explanatory power of results, all variables are processed with log transformation to obtain the following model:

$$\ln REV_{i,t} = \ln A + \partial_1 \ln J_{i,t-1} + \partial_2 \ln P_{i,t-1} + \partial_3 \ln Z_{i,t-1} + \varepsilon_{i,t-1}$$

Where, ε is a random error term. In addition, the sales revenue of new products and the R&D investment are all deflated by the price index published in the statistical yearbook, making the results more comparable.

C. Analysis of empirical results

1) Stationary test

The panel data combines characteristics of both cross-section data and time series data, so even it might be as same as the time series data, the panel data may also have a unit root, which causes a spurious regression phenomenon. Common unit root test methods include ADF test, LLC test and PP test. This work was consistent with at least two results. The results of EViews show that in the 0-order difference, the R&D personnel's full-time equivalent and R&D investment are stable time series, while the new product sales revenue and the number of effective patents are not stable. After the first-order difference, all sequences are stationary time series.

2) Variable intercept model of panel data

Because of the long-term equilibrium relationship, the original panel data can be processed directly. When selecting the type of variable intercept model, Hausman test value is 12.479, adjoint probability is 0.014, and the p value is less than the significance level 0.05. Therefore, the null hypothesis that the random error term is not related to the explanatory variable is rejected, and a fixed effect model is established. The results show that the elasticity coefficient of R&D expenditure of the previous period is 0.517337, which has a significant positive impact on the sales revenue of new products. It shows that the investment in R&D of industrial enterprises has a strong promotion effect on the improvement of technological innovation efficiency. For every 1% increase in R&D funds, the sales revenue of new products will increase by 0.52%. The reason may be that enterprises will pay more attention to improving the efficiency of technological innovation if they invest their own funds in research and development activities, and will quickly recycle research and development costs of enterprises by bringing research and development results to market. At the same time, the full-time equivalent of R&D personnel and the number of patents do not have a significant impact on the sales revenue of new products. Industrial enterprises have a narrow business scope, and there is no corresponding incentive mechanism for existing talents of enterprises, therefore, the enthusiasm of innovative talents is not high. In the process of cooperating with universities, research institutes and other institutions, their R&D personnel generally apply for patents but ignore whether research and development results can achieve market-oriented production.

3) Variable coefficient model of panel data

Beijing: SRBJ = -19.9550435418 + 7.05938798504 - 0.709184578629*ZLBJ + 0.168239777626*RYBJ + 2.42643968158*JFBJ

Tianjin: SRTJ = -15.9689808277 + 7.05938798504 - 0.364141635871*ZLTJ - 0.938084796341*RYTJ + 2.71866825363*JFTJ

Hebei: SRHB = -6.14549718115 + 7.05938798504 - 0.0265622561099*ZLHB - 0.140388493614*RYHB + 1.23131913949*JFHB

Liaoning: SRLN = -6.26111203245 + 7.05938798504 + 0.248870126603*ZLLN - 0.191940517393*RYLN + 1.10620008778*JFLN

Shanghai: SRSH = 34.1426381765 + 7.05938798504 + 0.851400562168*ZLSH + 0.547668868611*RYSH - 2.47877336007*JFSH

Jiangsu: SRJS = 2.61079726343 + 7.05938798504 + 0.27362013768*ZLJS - 0.0642656835658*RYJS + 0.446699540403*JFJS

Zhejiang: SRZJ = -5.54173311722 + 7.05938798504 + 0.27317319616*ZLZJ + 0.996391971015*RYZJ + 0.132051442046*JFZJ

Fujian: SRFJ = 18.4239381496 + 7.05938798504 + 0.673826224688*ZLFJ + 0.633376200394*RYFJ - 1.44336787444*JFFJ

Shandong: SRSD = -6.20938171971 + 7.05938798504 - 1.01462977786*ZLSD - 3.36997797664*RYSD + 4.29431032761*JFSD

Guangdong: SRGD = 4.90437483056 + 7.05938798504 + 0.379787904719*ZLGD - 0.263042819947*RYGD + 0.371509532404*JFGD

From the above-mentioned variable intercept model, it can be seen that the R&D investment industrial enterprises have a great influence on the sales revenue of new products in the current period, but the difference of the impact on different regions is still unknown. Therefore, it is necessary to use the variable coefficient model of panel data. The estimated results of EViews are shown in the figure. The goodness of fit of the model is 0.998556, and the fitting effect is good, indicating that the variable coefficient model has strong persuasive power.

The province with the largest elasticity of R&D investment is Shandong province. Shandong province has developed rapidly in recent years, and the total value of GDP ranks third of China. In 2015, its actual growth rate of GDP reached 8%, which was at the leading level in China. Its development of industrial enterprises is also very gratifying. Main business income, profits and taxes are ranked first in China. Although Beijing has less R&D investment, it attracts many innovative talents with its geographical advantages. However, its overall consumption level is high, and the price and cost of living are at the forefront of China, thus reducing the efficiency of R&D investment. At the same time, the innovation level of industrial enterprises in Beijing is generally high and the base is large, so it is difficult to improve at the original level. Similar to Beijing, Jiangsu and Guangdong are difficult to achieve breakthrough development on the original basis due to their location advantage.

IV. Summary and Suggestions

Through the above analysis, it is concluded that the number of effective patents and R&D personnel have no significant impact on the technological innovation ability, while the research and development expenditure of enterprises has a positive impact on technological innovation ability, and the regional elasticity coefficient with high investment amount is not high

Suggestions are as follows

(1) Making efforts to promote the introduction and training of scientific and technological talents is one of the most important factors in R&D activities. However, at present, the awareness of talent introduction and training of middle and small-sized enterprises is not strong, and there are very few talents with R&D capabilities. Therefore, enterprises should pay attention to strengthening technical cooperation with universities and research institutes, strengthen the market orientation of the "production, study and research" alliance, and encourage universities to establish internship bases and enterprise talents to enter universities for further study. At the same time, enterprises should also reward innovative talents with special professional skills or outstanding performance, so

as to maximize the potential of innovative talents and improve the return on intellectual investment.

(2) It is necessary to increase the R&D investment and focus on improving R&D ability. Industrial enterprises should have certain subjective initiative in the process of technological innovation and form a stable corporate innovation culture. Enterprises have to raise their awareness of R&D investment, increase investment in research and development funds, and set up special funds for research and development, which are earmarked for special purposes, so that the independent innovation ability of enterprises can be qualitatively changed.

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