

Research on R&D investment, patent output and enterprise performance: Empirical evidence from listed Chinese medicine companies

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ABSTRACT

With the vigorous development of knowledge economy, scientific and technological innovation has become a strong driving force for the rapid development of TCM industry. Based on the above background, this project will start with listed Chinese medicine companies and explore the correlation between R&D input, patent output and enterprise performance from the perspective of intermediary effect. This study will help enterprises enhance the level of patent output by adjusting the level of R&D investment, so as to improve the efficiency and effectiveness of R&D investment and promote the improvement of enterprise performance. Finally, this project will put forward some constructive practical countermeasures according to the analysis results.

KEYWORDS

R&D investment; Enterprise performance; Patent output.

1. INTRODUCTION

Traditional Chinese medicine culture is an important treasure of Chinese civilization, which has been paid more and more attention in recent years. In 2022, The State Council also issued the "14th Five-Year Plan for the Development of Traditional Chinese Medicine" to regulate and support the development of the traditional Chinese medicine industry. In the process of the prevention and control of the novel coronavirus epidemic, new patented traditional Chinese medicine prescriptions have also been widely used. At the same time, with the progress of technology, scientific innovation has become a key driving force to promote the development of the traditional Chinese medicine industry. Therefore, research on R&D investment, patent output and enterprise performance has become a key topic.

2. RESEARCH BACKGROUND

2.1. National policies support the breakthrough of TCM

In recent years, with the progress of the scientific development era and the economic reform, the development situation of traditional Chinese medicine has gradually improved. The "14th Five-Year Plan for the Development of Traditional Chinese Medicine" issued by The General Office of the State Council defines the overall development goals of traditional Chinese medicine during the "14th Five-Year Plan" period. Specific requirements and development plans have been put forward in TCM services, talent building, inheritance and innovation, cultural transmission and international cooperation, and it is expected to comprehensively improve the service capacity and governance level of TCM, and a series of goals and requirements have been put forward to improve the management

system of TCM and strengthen the emergency treatment capacity and guarantee of TCM, including the construction of a national TCM epidemic prevention and control base. The establishment and improvement of more sustainable and high-security policy systems have helped the development of traditional Chinese medicine.

2.2. The impact of COVID-19 on TCM industry

In the past three years, traditional Chinese medicine has made considerable contributions to the fight against the novel coronavirus (COVID-19) epidemic and related prevention and control. Many Chinese medicines, such as proprietary Chinese medicine granules, have played a huge practical role in the treatment process, and TCM related enterprises have also increased their research and development investment to produce more effective TCM products for the fight against the novel coronavirus epidemic and epidemic prevention and control. The National Health Commission and the State Administration of Traditional Chinese Medicine jointly issued a paper recommending their use to the whole country. And a number of proprietary Chinese medicines have also been included in the diagnosis and treatment program for medical observation. Statistics show that the use rate of traditional Chinese medicine in the treatment of COVID-19 has reached 91.5%, and the total effective rate of traditional Chinese medicine has also exceeded 90%.

2.3. Technological innovation promotes the take-off of TCM

In 2019, the Opinions of the CPC Central Committee and The State Council on Promoting the Inheritance, Innovation and Development of Traditional Chinese Medicine made important instructions on further improving the production methods of traditional Chinese medicinal materials. In addition, the development of drug extraction technology for plant species and the innovation of Chinese medicinal materials synthesis and drug induction technology have also opened a new situation for the development of traditional Chinese medicine. In addition, the emergence of traditional Chinese medicine packages that can be heated without boiling is an important reason for people to accept traditional Chinese medicine, and it is also a manifestation of the specific results of the development of traditional Chinese medicine brought about by technological innovation. The development of traditional Chinese medicine cannot be separated from technology, and the innovation and improvement of technology is the only way for the development of traditional Chinese medicine.

3. LITERATURE REVIEW

3.1. Domestic and foreign related literature and theory review

3.1.1. Research on the development plan of Chinese Medicine in the 14th Five-Year Plan

Xiao Wei (2022) believes that the "14th Five-Year Plan for the Development of Traditional Chinese Medicine" (hereinafter referred to as the "Plan") defines the guiding ideology, basic principles, development goals and key tasks for the development of traditional Chinese medicine from an overall perspective, and is a programmatic document for promoting the development of traditional Chinese medicine in China in the new era, which will effectively promote the development of traditional Chinese medicine industry into a new stage. The fruits of the development of traditional Chinese medicine will better benefit the people, and provide strong support for comprehensively promoting the construction of a healthy China and better protecting the health of the people.

3.1.2. Research on the application of TCM patented prescriptions under the new coronavirus epidemic

Zhang Boli, academician of the Chinese Academy of Engineering, believes that in the process of fighting the epidemic, traditional Chinese medicine has the following four contributions: First, for the "four categories of people" centralized isolation, widely provided traditional Chinese medicine, only Jiangxia shelter hospital's maximum daily supply of soup reached 37,778 bags, effectively reducing the positive rate of diagnosis, blocking the spread of the epidemic; The second is the treatment of mild/ordinary patients with traditional Chinese medicine into the shelter, taking decoction, proprietary Chinese medicine, acupuncture, massage, acupressure and other comprehensive treatment methods, taking Chinese medicine 100% of Jiangxia shelter hospital weight conversion rate is 0; Third, the combination of traditional Chinese and western medicine to treat severe patients, and the use of traditional Chinese medicine injections as soon as possible, in the key pathological links to turn the tide, four or two pounds; Fourthly, in the convalescence stage, the method of integrating traditional Chinese and Western medicine is adopted for rehabilitation treatment.

3.1.3. Cutting-edge research on existing enterprise performance evaluation methods

At present, the domestic methods to evaluate the performance of innovative enterprises mainly include economic added value method, DuPont financial evaluation method, balanced scorecard method and principal component analysis method. The current enterprise performance evaluation method in China takes input-output analysis as its core content, and follows the design concept of multi-factor combination analysis, combination of quantitative and qualitative analysis, and hierarchical progressive revision in index selection, which is obviously scientific, normative and rigorous. However, Zhu Chao (2019) found that there are still some problems in practice, such as the lack of independence and strict logic among the evaluation indicators in the enterprise performance evaluation system, insufficient attention to cash flow indicators, lack of indicators reflecting intangible assets of enterprises, and inaccurate calculation of evaluation indicators.

3.1.4. Research on the relationship between R&D investment and firm performance:

Jefferson(2001) found a positive correlation between R&D investment and performance. Wang Yihui (2013) concluded that R&D investment intensity can promote the performance of high-tech enterprises in China; Wu Weiwei (2008) found that the increase of R&D investment may not necessarily promote the innovation performance of enterprises, but may also inhibit it. Dong Mingfang (2016) made use of the data of listed companies in emerging industries and found that there is an inverted "N" type nonlinear relationship between the intensity of R&D input and the output of innovation performance.

3.1.5. Research on the relationship between patent output and firm performance

Griliches Zvi(1990) thought that "patent" was the best and most direct index to measure the level of innovation output. Ma Shengjie (2002) believes that the number of patent output can reflect the accumulation of technical knowledge and the technological innovation ability of enterprises. Li Mengchun (2007) took listed enterprises in China's pharmaceutical industry as the research object, and the results showed that there was a positive correlation between the patent output of listed enterprises in China's pharmaceutical industry and their future performance.

3.1.6. Research on the application of intermediary effect in the field of economic management:

An Cunhong and Zhou Shaoyan (2022) found that under the mediating effect of R&D investment, the spatial agglomeration of high-tech industries has a more significant impact on regional innovation performance, indicating the rationality of the combination of the two. In the annual research topic published by Zhang Shuguo (2021), the intermediary effect test indicates the way that digital finance affects the total factor productivity of enterprises, reflecting the application and promotion value of

intermediary effect. Based on the intermediary effect analysis of listed companies, Wu Qiang and Liu Zhian (2021) verified the impact mechanism of corporate tax burden on innovation research and development, reflecting the operability of intermediary effect on the study of internal relations. Mohamed Hamdoun, Mohamed Akli Achabou and Sihem Dekhili (2021) explored the relationship between corporate social responsibility and financial performance by introducing intermediate variables and using structural equation model method. These scholars' applied research on the mediation effect reflects its value and ability to be popularized.

3.2. A comprehensive review of domestic and foreign research results

As can be seen from the above research review, many scholars have studied the relationship between R&D investment and performance of enterprises, and the research direction is basically from the perspective of enterprises to conduct empirical test and analysis. Through the research review, it can be found that most foreign scholars draw the conclusion that the R&D investment of enterprises has a positive correlation with the performance, and there is a certain lag. However, domestic scholars started to study the relationship between R&D input and firm performance relatively late. Due to the impact of China's market economy reform and limited access to R&D data, domestic scholars have different research conclusions on the relationship between the two. At the same time, there are few literatures introducing the intermediary variable of patent output to conduct relevant research, which has great research value in this aspect.

4. RESEARCH DESIGN

4.1. research hypothesis

When other conditions are consistent, R & D input indirectly affects enterprise performance by affecting patent output.

4.2. Source of sample data

Based on the established empirical research practice in this paper, the relevant financial data of listed TCM enterprises from 2010 to 2022 are selected as the research samples, and the invalid data are processed accordingly. The data mainly comes from CSMAR and Juchao Information network.

4.3. Variable settings

4.3.1. Explained variables

In this study, enterprise value (Tobin Q) is selected as the explained variable, which can more directly reflect the performance indicators of enterprises. Tobin's Q is equal to (market value of equity + market value of debt)/total assets, where the market value of equity is measured by the share price of outstanding shares and the market value of debt is measured by the book value of debt.

4.3.2. Explanatory variables

The total R&D investment is selected as the explanatory variable, which reflects the various costs incurred by TCM enterprises in the research and development of products, technologies, materials, processes and standards.

4.3.3. Intermediate variables

The number of invention patents is used as the intermediary variable of this study. The "patent" is the best and most direct index to measure the level of innovation output.

4.3.4. Control variables

In this study, three control variables are selected, including total assets, return on total assets and asset-liability ratio.

The formula for calculating return on total assets: $\text{return on total assets} = \text{EBIT} / \text{average total assets}$.

The formula for calculating asset-liability ratio: $\text{asset-liability ratio} = \text{total liabilities} / \text{total assets}$.

Table 1. Variable definition table

Type of variable	Variable name	Variable symbol
Explained variables	Enterprise value	Value
Explanatory variables	Total R&D investment	R&D
Intermediate variables	Number of invention patents	Patent
Control variables	Total assets	Asset
	Return on total assets	ROA
	Asset-liability ratio	Debt

4.4. Model construction

With the help of the mediation effect model, this research project explores how R&D input with patent output as the intermediary variable affects firm performance.

Parallel mediation effect regression models were constructed, respectively as follows:

Model 1: $Y=cX+e_1$, that is, independent variable X and dependent variable Y were used to construct the regression model.

Model 2: $M=aX+e_2$, that is, the independent variable X and the intermediary variable M were used to construct the regression model.

Model 3: $Y=c'X+bXn+e_3$, that is, the independent variable X and the intermediate variable M together with the dependent variable Y were used to construct the regression model.

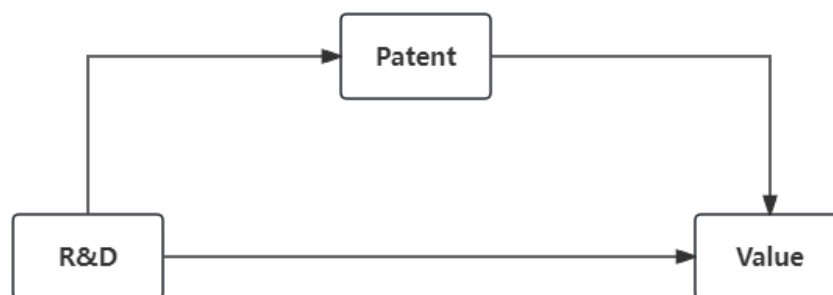


Figure 1. Schematic diagram of the intermediary effect model

5. EMPIRICAL ANALYSIS

5.1. Descriptive Statistics

According to the descriptive statistics table of variables, the maximum value of enterprise value (Tobin Q) is 24.915, the minimum value is 20.123, the average value is 22.248, and the standard deviation is 1.146, indicating that the difference of enterprise value of enterprises in the same industry is relatively small. As for the total amount of R&D investment and the number of invention patents, the gap between different enterprises is relatively large, indicating that different enterprises attach great importance to R&D investment. At the same time, the total asset size gap between enterprises

is also large. The average rate of return on total assets is 0.045, the overall level is low, and the difference is large within the industry. The average value of asset-liability ratio is 0.294, indicating a low overall level, indicating that the overall debt level of the industry is low and the financial risk is small, but the differences within the industry are still large.

Table 2. Variable descriptive statistics

Type of variable	Max	Min	Mean	Std
Enterprise value	24.915	20.123	22.248	1.146
Total R&D investment	6203288327.17	1440862.77	308125333.954	878143747.162
Number of invention patents	673	0	98.849	145.142
Total assets	66117789763.95	548746054.41	9012968946.566	13012749508.377
Return on total assets	0.259	-0.191	0.045	0.063
Asset-liability ratio	0.802	0.05	0.294	0.165

5.2. Correlation analysis

Pearson correlation test is used to analyze the variables, and the main variables selected in this paper were valid.

Table 3. Correlation Analysis

	Value	Total R&D investment	Number of invention patents	Total assets	Return on total assets	Asset-liability ratio
Value	1 (0.000***)	0.46 (0.001***)	0.332 (0.017**)	1.1460.819 (0.000***)	0.128 (0.371)	0.345 (0.013**)
Total R&D investment	0.46 (0.001***)	1 (0.000***)	0.489 (0.000***)	0.517 (0.000***)	0.185 (0.194)	-0.071 (0.619)
Number of invention patents	0.332 (0.017**)	0.489 (0.000***)	1 (0.000***)	0.228 (0.107)	0.185 (0.193)	0.013 (0.928)
Total assets	0.819 (0.000***)	0.517 (0.000***)	0.228 (0.107)	1 (0.000***)	0.11 (0.441)	0.237 (0.094*)
Return on total assets	0.128 (0.371)	0.185 (0.194)	0.185 (0.193)	0.11 (0.441)	1 (0.000***)	-0.404 (0.003***)
Asset-liability ratio	0.345 (0.013**)	-0.071 (0.619)	0.013 (0.928)	0.237 (0.094*)	-0.404 (0.003***)	1 (0.000***)

5.3. Intermediate effect test

The mediation effect analysis involves three types of models, which are as follows:

In model 1, independent variable X and dependent variable Y are used for regression model:

Company value = 21.378 + 0.0 * Total R&D investment - 19.158 * Net profit rate on total assets (ROA) + 19.057 * Return on assets + 0.0 * total assets

In model 2, independent variable X and intermediary variable M are used to construct regression models:

Invention patents =57.218+0.0 * Total R&D investment -893.711 * Net profit rate on total assets (ROA) +1081.873 * Return on assets -0.0 * total assets

In model 3, the independent variable X and the intermediate variable M together with the dependent variable Y were used to construct the regression model:

Company value =21.314+0.0 * Total R&D investment -18.167 * Net profit rate on total assets (ROA) +17.858 * Return on assets +0.0 * Total assets +0.001 * Invention patents

Through the intermediary effect test, this study can draw the conclusion that the intermediary effect is established, and R&D input affects enterprise performance by affecting patent output.

Table 4. Results of mediation effect test

Item	Test conclusion
Total R&D investment => Invention patent => Enterprise value	Significant mediating effect

6. CONCLUSION AND SUGGESTION

Through in-depth descriptive test, comprehensive correlation analysis and fine mediation effect test, this paper reveals the intrinsic relationship between R&D input, patent output and firm performance. We hope that by studying this relationship, we can provide the industry with a clear understanding and further promote the theoretical development of related fields.

On the basis of the analysis of the empirical test results, we put forward the following practical countermeasures to guide the direction of Chinese medicine enterprises in technology-driven development.

6.1. Strengthen enterprise R&D investment and management

Improve the enterprise's understanding of R&D investment and clarify the importance of R&D investment to the core competitiveness of enterprises. Companies should view R&D as a long-term investment, not a short-term one.

Establish and improve the management system of R&D investment to ensure the rational allocation and effective utilization of R&D investment. Enterprises should formulate appropriate R&D investment plans according to their own development needs, and strengthen the tracking and management of R&D projects.

Improve the professional quality of the enterprise R & D team and train technical innovation talents. Enterprises should increase the cultivation and introduction of talents, and provide continuous technical support and training for the research and development team.

6.2. Optimize the patent output structure

Focus on patent quality rather than quantity, and improve the patent authorization rate of enterprises. In the process of patent application, enterprises should pay attention to the innovation and practicality of patent technology and improve the quality of patent.

Strengthen the transformation of patent achievements and improve the efficiency of patent output. Enterprises should actively promote the industrialization of patented technological achievements and realize the deep integration of patented technological achievements and enterprise products.

Establish and improve the patent information service system to provide strong support for enterprise innovation. Enterprises should make full use of patent information resources, understand the industry technology development trend, and provide direction for enterprise research and development and innovation.

Through the above measures, Chinese medicine enterprises are expected to improve their own output level, promote the improvement of their own core competitiveness, and lay a solid foundation for achieving high-quality economic development.

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