

# Evaluation of Technological Innovation Capability of Listed Companies in Hebei Province

Duojiao Sun, Lu Hao

School of Accountancy, Hebei University of Economics and Business, Shijiazhuang, Hebei, China

## **Abstract:**

Taking listed companies in Hebei Province from 2015 to 2020 as a research sample, by using Comparative analysis and Principal component analysis, this paper evaluates the technological innovation capability of listed companies in Hebei Province from three aspects of innovation environment, innovation input and innovation output. This paper finds: (1) The technological innovation capability of Hebei is weaker than that of the whole country, but it shows an upward trend; (2) There are problems such as insufficient innovation capability and lack of scientific achievements in the listed companies of Hebei. Then, this paper proposes solutions from the perspective of government and listed companies, such as adding more innovation preferential policies, enhancing the innovation consciousness of senior managers, and optimizing the allocation of human resources. The conclusion of this research can provide basis for listed companies to optimize innovative development strategies and improve technological innovation capability effectively, and also provide basis for relevant departments to adjustment policies and investors to avoid investment risks.

**Keywords:** *Principal component analysis, Technological innovation, Listed companies.*

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## I. INTRODUCTION

The Eighteenth National People's Congress proposed that we need to implement the innovation-driven development strategy and emphasized that scientific and technological innovation is a strategic support for improving social productivity and comprehensive national strength. Innovation is the general trend and the present development situation. The traditional development impetus and extensive growth modes cannot support the realization of the current strategic goals. Our country needs to rely on innovation to foster new economic growth points, improve the quality and efficiency of the economic development continuously, and open up new space for development. Innovation, as the basis for the survival and development of enterprises, is one of the effective ways to enhance market competitiveness of companies, it also helps the enterprise to optimize the organizational structure, increase productivity, and adapt to the requirements of economic development better. Science and technology are the primary productive forces, and technological innovation capability has become one of the necessary capabilities for the development of modern enterprises.

Hebei Province is located in the center of the Bohai Bay. As an important part of the Beijing-Tianjin-Hebei regional economy and the Bohai economic circle, it takes on the important task of undertaking non-capital functions. Hebei Province has an excellent geographical location, which surrounds the political center—Beijing. Hebei is rich in resources, and its coal and oil resources have advantages in China. In addition, the industrial structure of Hebei Province is distinctive, and its traditional industries such as steel and equipment manufacturing have developed steadily. From 1980 to 2019, the GDP of Hebei Province has always ranked among the top ten in China, which means Hebei Province is a veritable economic province, and occupies a very important political and economic position in the country. Since the 13th Five-Year Plan was proposed, the Central People's Government of China has put forward fully implementing the innovation-driven development strategy. To respond to the national appeal actively, Hebei vigorously promotes the development of scientific and technological innovation. However, the industrial structure of Hebei Province is still dominated by traditional manufacturing with low technological content, the innovation foundation is weak, the development time of technological innovation ability is short, the innovation ability evaluation system is not perfect enough, and there is a lack of a more authoritative evaluation system.

From the perspectives of innovation environment, innovation input and innovation output, this paper evaluates the technological innovation capability of listed companies in Hebei Province, and puts forward specific suggestions according to the research conclusions. The research in this paper enriches the content related to the technological innovation capabilities of listed companies in Hebei Province, provides basis for listed companies to optimize innovative development strategies and improve technological innovation capability effectively.

## II. LITERATURE REVIEW

### 2.1 Domestic Researches on Technological Innovation of Enterprises

There were some domestic researches on innovation capability, which evaluated and analyzed the technological innovation capability and driving factors of enterprises from the perspectives of regions, industries, and types of enterprises. Li Zhengdong and Li Wei <sup>[1]</sup> (2021) analyzed the status and changes of technological innovation capabilities of small and medium-sized enterprises in Xuzhou of Jiangsu, proposed an evaluation model for technological innovation capabilities, and put forward relevant suggestions from three aspects such as optimizing endogenous innovation elements; by making a field survey on high-tech enterprises in 7 cities in China, and designing a Logit regression model, Wei Ping and Tang Yaqian <sup>[2]</sup> (2020) conducted an empirical study on the main driving factors, and found that innovation strategies, innovation investment, innovation modes and enterprise scales had an impact on the innovation ability of high-tech enterprises in China; Li Zengfu et al. <sup>[3]</sup> (2021) explored the impact of non-state-owned capital participation on the technological innovation of state-owned enterprises, and found that it mainly promotes the technological innovation of state-owned enterprises by strengthening internal control and improving executive compensation incentives; Ma Shuyan et al. <sup>[4]</sup> (2021) took 28 national high-tech zones in the Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta urban agglomerations as the

research objects, and discovered that the average innovation efficiency of the national high-tech zones in the Beijing-Tianjin-Hebei urban agglomeration were the lowest, and the change of innovation efficiency showed a "U"-shaped downward trend.

## 2.2 Researches on Enterprise Technology Innovation in Hebei Province

In recent years, lots of scholars investigated and researched enterprises in different industries in Hebei Province from some perspectives such as innovation status and innovation efficiency, and put forward many valuable suggestions based on the research results and current development trends. Li Baihua et al.<sup>[5]</sup> (2019) measured the technological innovation activities in Hebei Province from 2004 to 2015 and found that the regional economic scale and innovation environment had a positive effect on technological innovation efficiency, while regional industrial structure had a negative and significant impact on technological innovation efficiency. Based on this, they put forward the path of technological innovation improvement such as increasing innovation investment and optimizing industrial structure; Liu Huan, Wang Aimin<sup>[6]</sup> (2014) analyzed the technological innovation of private enterprises in Hebei Province, summed up the main advantages, disadvantages, opportunities, challenges of technological innovation and technological upgrading of private enterprises, and put forward effective development paths; Liu Man et al.<sup>[7]</sup> (2018) summarized and analyzed the problems existing in the technological innovation of leading agricultural industrialization enterprises in Hebei Province, then proposed a few countermeasures, for example optimizing the allocation of innovation resources, accelerating the joint innovation and construction of agricultural industries; based on an empirical study on the technological innovation efficiency of new economy listed companies in Hebei Province, Song Zhibian et al.<sup>[8]</sup> (2019) found that scale efficiency, technological spillovers and other comprehensive environmental factors were not conducive to the improvement of technological innovation efficiency of enterprises, and made corresponding recommendations.

## 2.3 Issues Worthy of Attention in The Existing Literatures

There are a large number of literatures related to technological innovation in China, but their research perspectives are mostly based on industries and regions. Those researches select industries with superior economic development prospects or regions with outstanding innovation and development, and analyze the technological innovation capability of enterprises within industries and regions. However, there is a lack of analysis on the innovation capability of enterprises in industries with low technological content but supporting regional economic development. In addition, there are few studies of the same type in Hebei Province at present. In the selection of research objects, the existing literature tends to choose enterprises with effective innovation and development and strong economic strength, ignores to research the technological innovation capabilities of other enterprises. At the same time, the sample data of some literatures is too old, the results may not suitable for the innovation and development of current enterprises.

### III. INDICATOR SELECTION AND DATA DESCRIPTION

Referring to the index system of Chinese innovation and combining with the availability of data and regional characteristics, this paper selects 6 indicators from innovation environment, innovation input, and innovation output, as shown in TABLE I.

The innovation environment includes:

(1) *per-capita GDP*: reflects the interdependence and mutual promotion between economic growth and the development of innovation capacity;

(2) *Proportion of science and technology appropriation to financial appropriation*: the national financial science and technology expenditure is used as an indicator of science and technology appropriation, reflects the government's direct investment in innovation and the planning and guiding roles of the most important areas, crucial regions and frontier fields;

(3) *Research and development (R&D) investment intensity*: means the ratio of R&D investment to GDP.

Innovation input includes:

(1) *R&D investment*: reflects the level of scientific and technological innovation investment of enterprises;

(2) *R&D personnel investment*: reflects the investment scale and intensity of innovative manpower.

The innovation output includes:

*The number of scientific research achievements*: takes the number of scientific and technological achievements registered by the Hebei Provincial Department of Science and Technology as an indicator, includes patented technology, project research and other scientific research achievements, and reflects the relevant situation of innovation output.

**TABLE I. The selection of technical innovation ability indicators**

INDICATOR CATEGORY	INDICATOR DESCRIPTION
INNOVATION ENVIRONMENT	Per-capita GDP
	Proportion of science and technology appropriation to financial appropriation
	Research and development (R&D) investment intensity

INNOVATION INPUT	R&D investment
	R&D personnel investment
INNOVATION OUTPUT	The number of scientific research achievements

This paper takes 61 listed companies in Hebei Province as samples and evaluates their technological innovation capabilities based on the relevant data from 2015 to 2020. The data used in the evaluation process are from the Hebei Provincial Department of Science and Technology, Hebei Provincial Bureau of Statistics, the municipal governments and the municipal statistics bureau to which the listed companies belong. As of December 31, 2020, there are a total of 61 listed companies in Hebei province. According to the industries involved, the samples include 9 types of industries such as mining, real estate and manufacturing. There are 46 manufacturing enterprises, accounting for 75.41%, 1 comprehensive enterprise, and no more than 3 companies listed in other industries; according to the listed sectors, 13 companies are listed on the Shenzhen A-share main board, 11 are listed on the SME board, 14 are listed on the second board, and a maximum of 23 companies are listed on the Shanghai A-share main board; according to the number of years that companies have been listed, the company with the longest listing time has been listed for 28 years since 1994, and the company with the shortest listing time has been listed for 2 years since 2020; according to the region where the company is located, there are 17 companies in Shijiazhuang and 10 in Tangshan, 8 companies in Baoding, 5 companies in Cangzhou, 4 companies in Qinhuangdao, and the remaining companies are located in 10 regions including Chengde, Handan and Hengshui, with no more than 3 companies in each region.

## IV. DATA ANALYSIS

### 4.1 Innovation Environment

#### 4.1.1 Per-capita GDP

As shown in Fig 1, the per-capita GDP of Hebei Province has increased yearly, from 35,653 yuan in 2015 to 48,564 yuan, with an increase of 36.21%, and shows an upward trend. Among them, the growth rate was faster in 2016, with an increase of 7.24% compared with the previous year, and the growth rate in 2020 was slower, with an increase of only 5.16%. During the same period, the national per-capita GDP showed a slow upward trend, especially in 2020, compared with the previous year, the per-capita GDP increased by only 2.19%, and the growth rate dropped by about 7 percentage points, and reached the lowest level in six years. Compared with the national data, the per-capita GDP of Hebei Province was still low, the gap between them increased year by year, and reached a maximum value of 24,710 yuan in 2019. On the whole, the economic development of Hebei Province has a relatively weak advantage. In the environment where the national per-capita GDP growth rate has slowed down significantly, the per-capita GDP of Hebei Province can still rise steadily at a growth rate of more than 5%. It indicates that the economic development of Hebei Province is relatively good, which creates a stable economic environment

for the improvement of Hebei Province's technological innovation capabilities.

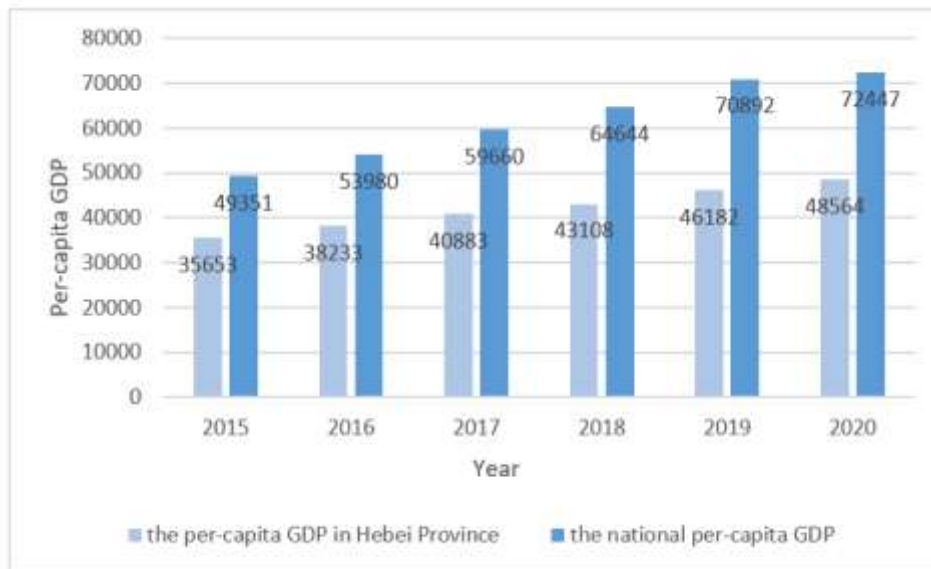


Fig 1: The per-capita GDP

This paper analyzes the slowdown of the per-capita GDP growth rate in Hebei Province in 2018, and finds that, on one hand, due to the lack of matching between the leading industries and the rapid development of the economy, the loss of labor force and some other reasons, the province's resident population in 2018 was higher than the previous year, although the GDP decreased by 9.6% compared with 2017, the GDP of 7 of the 11 cities in the province showed a negative growth. However, with the release and implementation of a large number of policies, the industrial transformation accelerated, the provincial economy recovered in 2019, surpassed the all-time high in 2020 and achieved positive growth in the province's GDP; on the other hand, affected by domestic and foreign factors such as the vicious changes in Sino-US trade relations and the negative growth of automobile consumption, the national GDP growth rate was slower than that in 2017. The growth rate of per-capita GDP in Hebei Province decreased by 1.5 percentage points compared with the previous year, which was similar to the decline in the national per-capita GDP growth rate during the same period.

#### 4.1.2 Proportion of science and technology appropriation to financial appropriation

According to the "Statistical Bulletin of Hebei Province's Science and Technology Investment" jointly issued by the Hebei Provincial Bureau of Statistics, the Department of Science and Technology and the Department of Finance, the overall financial science and technology expenditure in Hebei Province was on the rise, with the lowest point being 4.55 billion yuan in 2015 and the highest point being 10.176 billion yuan in 2020, the difference between them was about 124%, of which the increase in fiscal science and technology expenditure in 2016 reached 60.84%, while the expenditure in 2017 showed a negative growth. After the analysis, it is believed that to respond to the requirements of the "13th Five-Year Plan" for

scientific and technological innovation capabilities actively, achieve the goal of innovation and development, Hebei Province greatly increases the financial science and technology expenditure, but the continuous high-intensity investment in innovation needs the support of a high-speed growth economy. The GDP of Hebei Province in 2017 increased by 6.7% over the previous year, and the economic development was stable with progress, however, stable economic development cannot meet the needs of high-intensity innovation investment. Continuing to increase innovation investment may cause some economic pressure on Hebei Province and affect the smooth progress of other economic activities.

The proportion of science and technology appropriation in Hebei Province was on the rise as a whole, and the change was relatively flat. In 2016, the proportion was 1.21%, reaching the highest level in six years, and increased by 4 percentage points over the previous year, compared with the same period of time, the change in the proportion of 2016 is relatively large, as shown in Fig 2. It indicates that Hebei Province's investment in innovation has increased year by year, the government's emphasis on and support for technological innovation capabilities has increased significantly, and the technological innovation capabilities of Hebei Province have improved. However, because of the limitations of the slowly developing provincial economy, the flawed industrial structure, imperfect resource allocation and many other factors, the overall technological innovation capability of Hebei Province is still relatively weak.

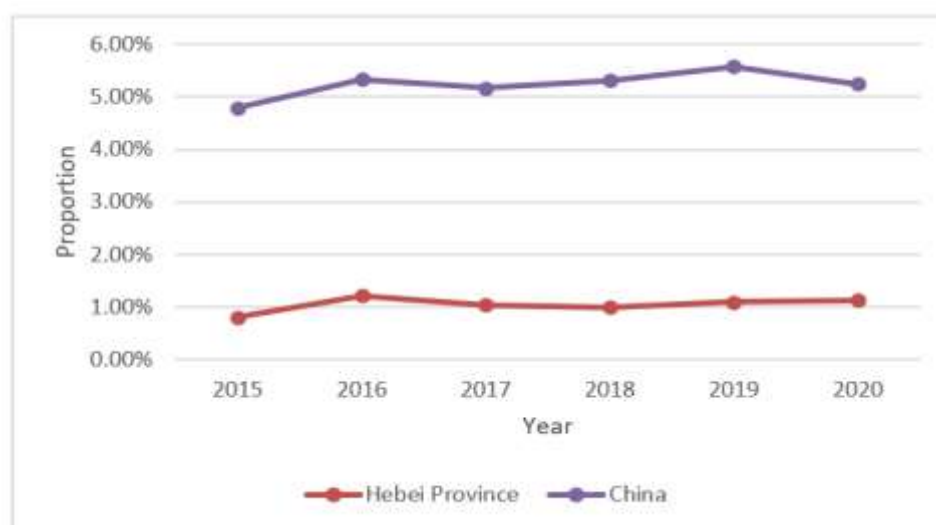


Fig 2: Proportion of science and technology appropriation to financial appropriation

#### 4.1.3 Investment intensity of research and development (R&D) funds

R&D investment refers to the total expenditure actually used by the whole society for basic research, applied research and experimental development funds, and reflects the society's investment and emphasis on innovation. In 2015, Hebei Province invested a total of 35.09-billion-yuan in R&D funds, with an investment intensity of 1.18%, then the investment gradually increased at an average annual rate of 16% to 63.44-billion-yuan in 2020, with an increase in investment intensity of 1.75%, showing a slow upward

trend as a whole. The proportion of investment in basic research and applied research has increased. In 2019, the total investment in basic research in Hebei Province reached 1.49-billion-yuan, accounting for 2.6% of R&D funds, the proportion of R&D expenditure increased by 0.7 percentage points compared with 2015; applied research funds reached 5.8-billion-yuan, accounting for 10.2% of R&D funds, the proportion increased by 1.4 percentage points compared with 2015, and the R&D structure had been optimized and improved. From the perspective of the main activities, in 2015, the proportion of R&D expenditures of enterprises, government-affiliated research institutions, and colleges and universities were 83.8%, 11.5%, and 4.0% respectively, the proportion of R&D expenditures of enterprises was relatively high.

Since the "Thirteenth Five-Year Plan", the average annual growth rate of R&D expenditure of enterprises, government-affiliated research institutions and colleges and universities has been 0.5%, -0.58%, 0.1%, and the proportion of R&D investment in the province has been adjusted to 86.3%, 8.6%, 4.5%, the role of enterprises in innovation investment has been relatively enhanced, the innovation investment of colleges and universities has increased, the innovation investment of government-affiliated research institutions has been significantly reduced, and the overall technological innovation capability of Hebei Province has improved.

As shown in Fig 3, compared with the national R&D investment intensity, the investment intensity of Hebei Province from 2015 to 2020 was still relatively low, and the difference between 2015 and the same period in the country was 0.9 percentage points. With the increase of R&D investment, the gap gradually narrowed. By 2019, the difference was only 0.4 percentage points, but its growth trend was basically the same as that of the whole country, maintaining a continuous positive growth, with an average annual growth of 0.11 percentage points slightly higher than the national increase of 0.07 percentage points in the same period. It shows that Hebei Province has achieved remarkable results in the in-depth implementation of the innovation-driven development strategy, the technological innovation capability of Hebei Province is still lower than the national level. However, since the "Thirteenth Five-Year Plan", provinces, cities and counties have worked together to implement various tasks and goals, the number of innovative entities in the province has increased sharply, the proportion of enterprise innovation investment in total R&D investment has been increasing, and R&D expenditure of enterprises have accounted for more than 85% of the province's total R&D investment. Enterprises gradually occupy the main position of R&D investment in the province, become an important force supporting the growth of R&D investment, have a great impact on the growth of Hebei Province's total R&D investment, and drive the further improvement of Hebei Province's overall technological innovation capability.



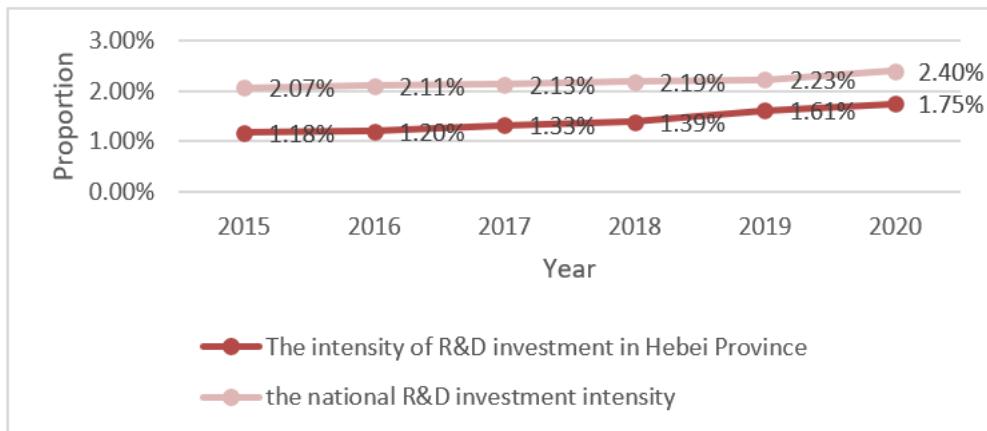


Fig 3: Investment intensity of research and development (R&D) funds

## 4.2 Innovation Input

### 4.2.1 R&D investment

The total R&D investment of listed companies in Hebei Province has increased year by year. As shown in Fig 4, the total R&D investment in 2020 reached 9.735 billion yuan, and had an increase of 241.55% compared with the total investment of 2.85 billion yuan in 2015. During the same period, the total R&D investment of enterprises in Hebei Province increased from 29.51 billion yuan to 54.62 billion yuan, with an increase of 85.08%, which was far lower than the growth rate of R&D expenditure investment of listed companies. The number of listed companies in Hebei Province is relatively small, and the proportion of enterprises in the province is low. In 2020, the total R&D investment of listed companies accounted for 17.82% of the total R&D investment of enterprises in Hebei Province in the same period, and the proportion had increased about 8 percentage points compared with 9.66% in 2015. At all events, the increase in the total R&D investment of listed companies has a limited impact on the total R&D investment of enterprises in Hebei Province. The total R&D investment in Hebei Province is still low, and the technological innovation capability in the province is quite weak.

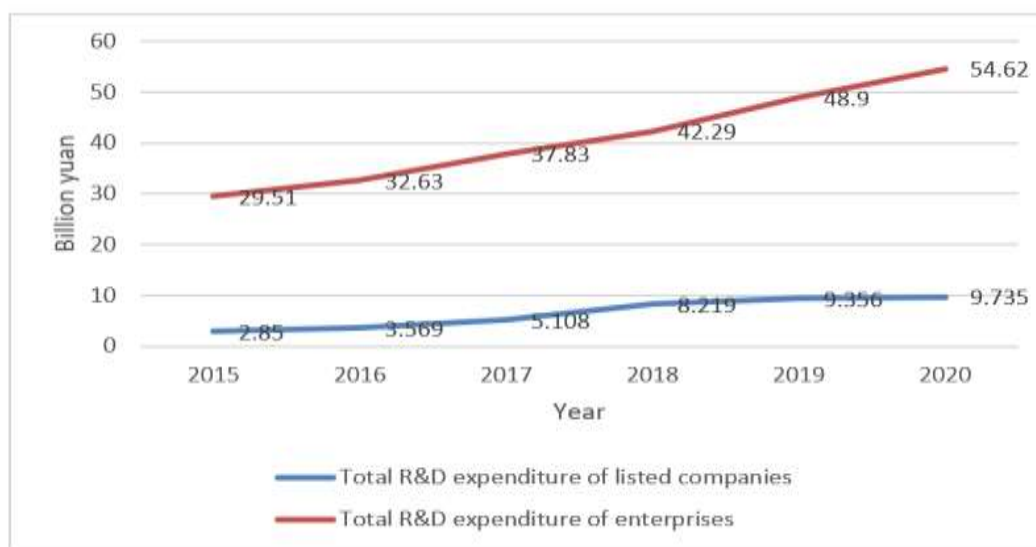


Fig 4: Enterprise R&D expenses in Hebei Province

According to the perspective of the changing trend, the R&D expenses of listed companies shows an upward trend of rapid growth and then slow growth. In 2018, the growth rate was the fastest, with an increase of 60.9%. In 2020, the growth rate slowed down, with an increase of only 4.05% compared with the previous year, as shown in

Fig 5. With the changes in the domestic and foreign trade and economic environment, the incentives for R&D investment of foreign-funded enterprises in China continue to decline in recent years, and some domestic regional economies are facing greater downward pressure. Since innovation activities are more affected by the economic environment than other economic activities, the growth of R&D investment of enterprises in Hebei Province has slowed down significantly, and the growth rate of R&D investment of listed companies has dropped, which is about 6 percentage points lower than the growth rate of total R&D investment in Hebei Province and the whole country. Affected by the epidemic, in 2020, the market environment deteriorated, funds were tight, consumption declined, the operating income of enterprises was greatly reduced, the growth rate of profits was significantly reduced, some enterprises' profits even showed a negative growth trend. Profit is the most important source of funds for corporate innovation investment, its slowdown definitely affects R&D investment. In addition, the securities market has strict requirements on the profitability of listed companies, and the slowdown in the growth rate of R&D investment may be one of the ways for listed companies to adjust the profit structure and maintain a profitable state by reducing investment in research and development expenses in order to adapt to the adverse impact of the epidemic on the enterprise economy.

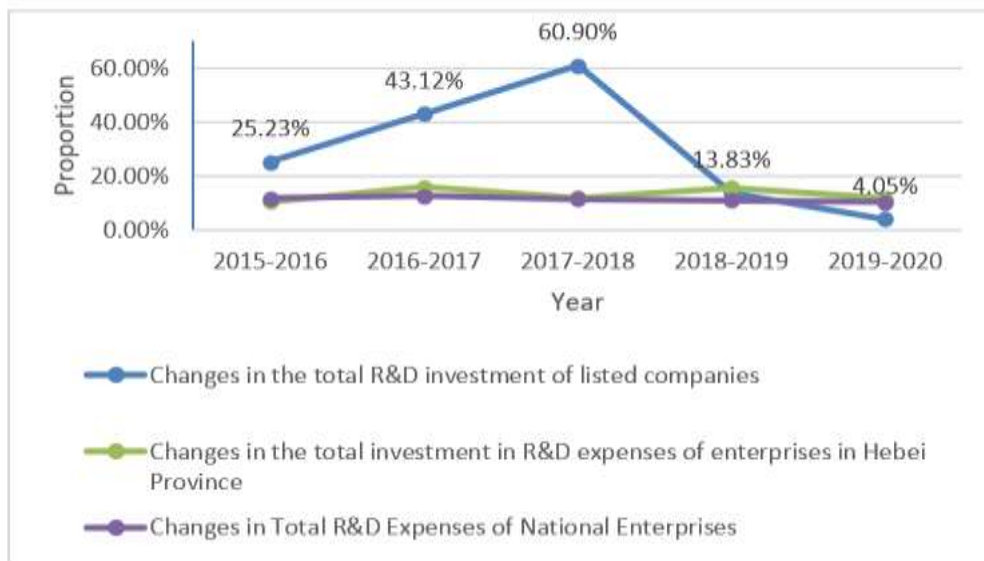


Fig 5: Changes in total R&D expenses

#### 4.2.2 R&D personnel investment

According to the data obtained from the annual financial statements of listed companies, it finds that the number of R&D personnel in listed companies is related to factors such as company size, management's emphasis on technological innovation, and company operations. This paper uses the average ratio of the number of R&D personnel to the total number of companies as an indicator to measure the investment of R&D personnel in listed companies. The analysis finds that the proportion of R&D personnel was not stable enough from 2015 to 2020, and fluctuated frequently, but the fluctuation range was small, and the overall trend showed a downward trend, as shown in

Fig 6. The proportion reached 19.08% in 2015, dropped to 18.29% in the following year, then continued to rise to the highest point of 19.21% with an average growth rate of 0.5 percentage points, and dropped again to 17.93% in 2020. The decline rate is approximately the same as that in 2016, and the proportion of technical personnel is only 0.1 percentage points higher than the lowest point. Comparing the two declines in 2015-2016 and 2019-2020, the reasons are as follows. On one hand, listed companies have higher requirements for the professional ability of R&D personnel, and pay more attention to the technical ability of R&D personnel rather than the number, some researchers who do not meet the requirements will be eliminated. At the same time, the demand for material and economic resources provided by the company has increased, resulting in an increase in the company's R&D expenses and a decrease in the proportion of R&D personnel; on the other hand, changes in the economic environment have a certain degree of impact on the company's business conditions, the impact of the epidemic in 2020 has caused the province's economy to decline. Although the gross national product can still maintain positive growth, the growth rate is far lower than the previous level. The slowdown in economic development and the stagnation of consumption caused by the epidemic have forced the company to reduce the input of expenses and the number of R&D personnel to avoid a sharp drop in profits and affecting the normal operation of the company.

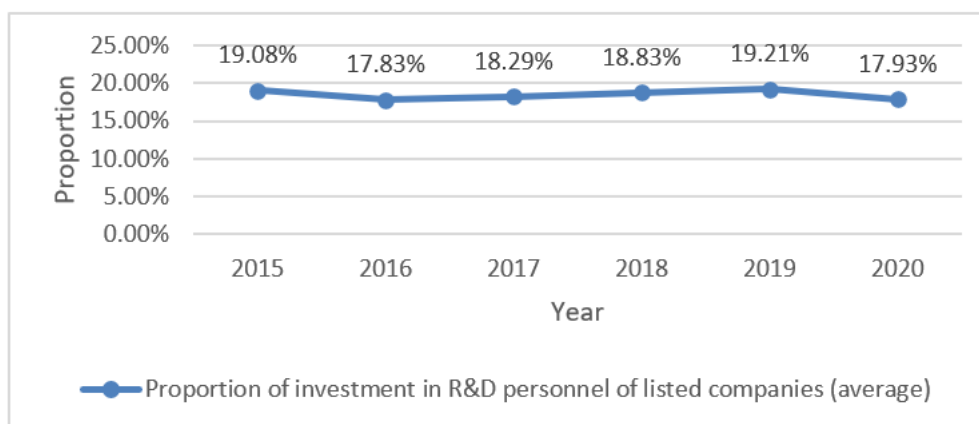


Fig 6: Proportion of R&D personnel in listed companies

As of 2020, the full-time equivalent of R&D personnel in Hebei Province totaled 125,058 person-years, and the full-time equivalent of basic research, applied research, and experimental development personnel were 8,293, 19,083, and 97,682 person-years, accounting for 6.63%, 15.26%, and 78.11%. Compared with 2015, the total value of full-time equivalents increases by 16.9%, the full-time equivalents of basic research and applied researchers increase by at least 1.4 percentage points. The innovative entities tend to invest in R&D personnel gradually towards basic research and applied research.

However, experimental development is still the focus of investment. Compared with the full-time equivalent of the national R&D personnel during the same period, from 2015 to 2020, the full-time equivalent of the national R&D personnel increased by 39.26%, the increase was significantly higher, and the average level of domestic technological innovation capabilities had been greatly improved. In 2020, basic research accounted for the full-time equivalent proportion of R&D personnel reached 8.15%, the adjustment range was 1.4 percentage points, and the proportion of applied research reached 12.33%, an increase of 0.7 percentage points over 2015, the increase was basically the same as that of Hebei Province. The proportion of full-time equivalents of applied research R&D personnel in Hebei Province has increased relatively large, the input of R&D personnel is nearly 3 percentage points higher than the national level, and the full-time equivalent ratio of basic research R&D personnel is slightly lower, 1.5 percentage points lower than the national level. During the statistical period, each innovation subject closely followed the changes in national policies, combined with the company's economic structure, timely revised the focus of R&D personnel input, optimized the use of human resources, and effectively improved the technological innovation ability. However, compared with the national average, Hebei Province's R&D personnel input the focus is still deviated, the total value of the full-time equivalent of R&D personnel is relatively low, and the overall technological innovation capability is still weak.

From the perspective of changes, as shown in Fig 7, the full-time equivalent of R&D personnel in Hebei Province has a V-shaped change, and the growth rate has gradually decreased from 4.12%. In 2018, there was a negative growth trend, with a growth rate of -8.76%. The province's R&D personnel

investment decreased sharply, the full-time equivalent of R&D personnel reached the lowest level since the "13th Five-Year Plan", then the growth rate picked up in 2019 and reached the highest growth rate of 11.86% in 2020. During the same period, the change in the full-time equivalent of R&D personnel across the country showed a slow upward trend, with an average increase of 3.5 percentage points from 2015 to 2017. Since 2018, the growth rate has increased to more than 8%, with a maximum of 9.57%. In 2020, the growth rate was slightly lower than that of the previous year, but it still maintained a high-speed growth rate of 9%. Compared with the changes in the full-time equivalent of R&D personnel across the country, Hebei Province had a large fluctuation range and a significantly poorer stability. Except for 2015 and 2020, the growth rate was lower than the national level, but overall, its growth trend was relatively good. This shows that the full-time equivalent of R&D personnel in Hebei Province has increased, the investment in R&D personnel is increasing, and the technological innovation capability of Hebei Province has developed to a higher level. Anyway, at present, the technological innovation capability of the province is still obviously weak, and the allocation of R&D personnel resources is not optimized enough, which needs to be further improved.

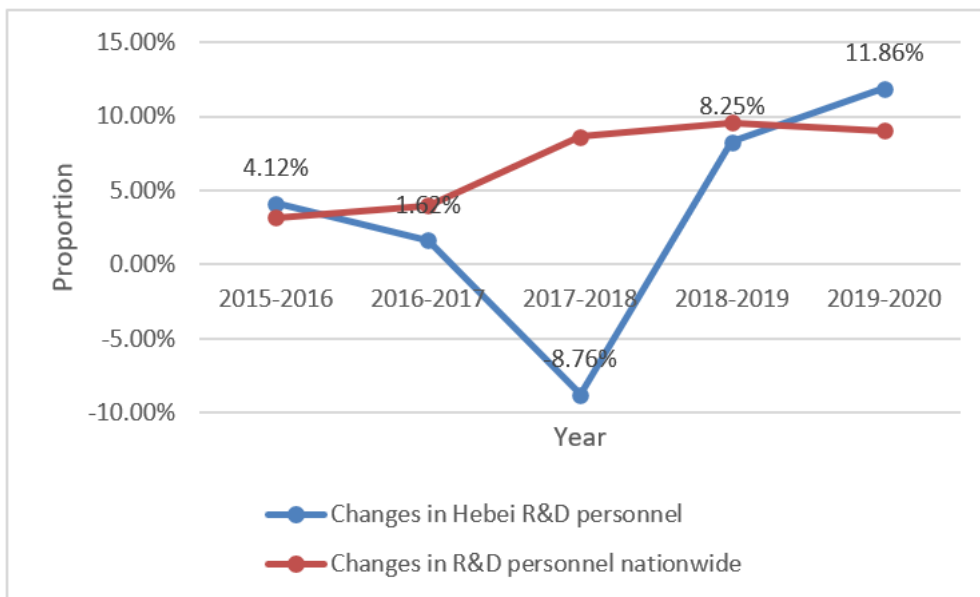


Fig 7: Changes in R&D personnel input

### 4.3 Innovation Output

#### 4.3.1 The number of scientific research achievements

Due to limited data release, only the data related to the registration of scientific research achievements from 2015 to 2018 was analyzed. In 2018, the province registered a total of 2,678 scientific and technological achievements, mainly applied technology achievements, accounting for 93.07% of the total number of registrations, and a total of 1,724 achievements that reached the domestic advanced level or above, accounting for 64.38% of the total. The level of innovation output in Hebei Province was higher,

more emphasis was placed on innovative research in applied technology. Divided by registration institutions, medical institutions registered 1,664 items, accounting for 62.14% of the total. They were the main completion units of scientific and technological achievements, and achieved more than half of the province's innovation output. And there were 375 enterprise registrations, accounting for only 14% of the total, an increase of 4 percentage points compared with the previous year. This indicates that the number of scientific and technological achievements of enterprises has been further improved, and the innovation structure has been effectively optimized, but the number of innovation outputs is still low. High-intensity investment in innovation has not significantly improved the level of innovation output, and the technological innovation capability of enterprises still needs to be improved. As shown in

Fig 8, the number of listed companies' scientific research achievements in 2018 totaled 53, an increase of 28 compared with 2015, and the percentage of increase was 112%. The level of innovation output of listed companies has increased significantly, which is comparable to the number of registered scientific research achievements of enterprises in the province. In comparison, the number of scientific research achievements of listed companies is significantly smaller, and the technological innovation capability is still weak.

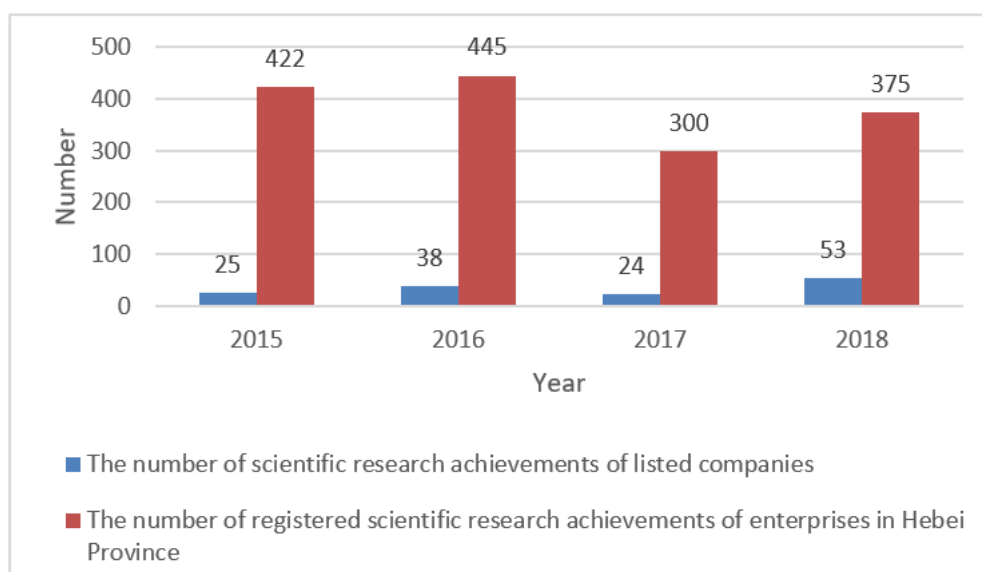


Fig 8: The number of scientific research achievements registered

As one of the important components of intellectual property rights, the number of patents can reflect the innovation ability and market competitiveness of innovative entities. However, due to the continuous changes in the economic environment, some patent rights with poor market prospects will expire early. Therefore, the number of valid patents, compared with other indicators, can better measure the level of innovation output. As shown in Fig 9, the number of valid patents in Hebei Province reached 266,100 in 2020, an increase of 208% over 2015, showing a rapid upward trend. Among them, the largest increase in 2019-2020 was 36.16%, an increase of 14 percentage points over the previous year, which was about 9 percentage points higher than the increase in the number of valid patents nationwide in the same year, the

implementation of the innovation-driven strategy had achieved remarkable results. During the statistical period, the change trend of the number of valid patents in Hebei Province and the whole country is basically the same, and the growth rate of the number of valid patents in Hebei Province has significantly exceeded the national level in the same period, indicating that the innovation output of Hebei Province has been increasing, and the technological innovation capability has been improved year by year.

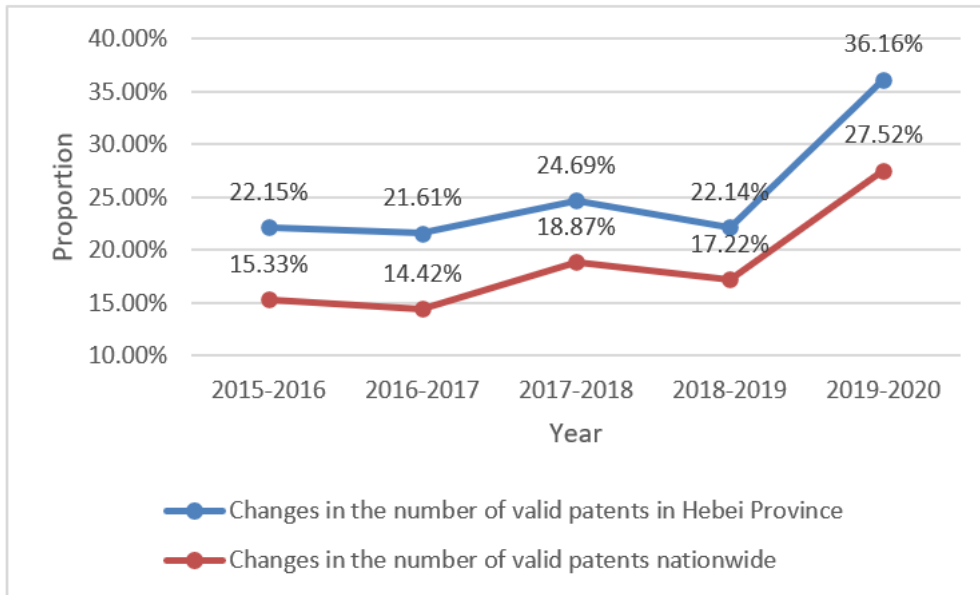


Fig 9: Changes in the number of valid patents

#### 4.4 Further Analysis

In order to evaluate the technological innovation capabilities of enterprises in Hebei Province more accurately and effectively, this paper selects 6 indicators including per-capita GDP, applies a comprehensive evaluation method, processes the data with the help of SPSS21 software, and uses the principal component analysis method to analyze and evaluate the technological innovation status of the listed companies in Hebei Province from 2015 to 2020, designs a comprehensive evaluation model, namely model (1).

$$y = \sum_{i=1}^m \beta_i F_i \quad (1)$$

$$\left\{ \begin{array}{l} F_1 = C_{11}X_1 + c_{12}X_2 + \dots + c_{1n}X_n \\ F_2 = C_{21}X_1 + c_{22}X_2 + \dots + c_{2n}X_n \\ \vdots \\ F_i = C_{i1}X_1 + c_{i2}X_2 + \dots + c_{in}X_n \end{array} \right.$$

Among them:  $y$  is a comprehensive evaluation index,  $\beta_i$  is the variance contribution rate of each principal component  $F_i$ , and  $x$  represents each different index, as shown in

TABLE II.

**TABLE II. Technological Innovation Capability Index System**

VARIABLE	INDEX
$X_1$	Per-capita GDP
$X_2$	Proportion of science and technology appropriation to financial appropriation
$X_3$	Research and experimental development (R&D) investment intensity
$X_4$	R&D investment
$X_5$	R&D personnel investment
$X_6$	The number of scientific research achievements

This paper uses SPSS software for principal component analysis, and the eigenvalues, cumulative variance contribution rate and component score coefficient of the principal components are shown in TABLE III. It can be seen that the variance contribution rates of the two principal components are 55.008% and 26.098%, and the cumulative contribution rate is 81.106%. Therefore, the first two principal components are used as the final evaluation indicators, and the eigenvalues of the two principal components are 3.300 and 1.566 respectively.

**TABLE III. Eigenvalues of principal components, cumulative variance contribution rate, and component score coefficients**

INGREDIE NTS	INITIAL EIGENVALUES			EXTRACT SUM OF SQUARES AND LOAD			INGREDIE NTS	
	TOT AL	VARIAN CE %	ACCUMULAT ION %	TOT AL	VARIAN CE %	ACCUMUL ATION %	1	2
1	3.300	55.008	55.008	3.300	55.008	55.008	.318	.009
2	1.566	26.098	81.106	1.566	26.098	81.106	-.001	.474
3	.878	14.633	95.739				.325	-.045
4	.243	4.045	99.784				.345	-.083
5	.013	.216	100.000				.163	-.562
6	1.001 E-013	1.015E- 013	100.000				.057	.194

Values with larger absolute values in the factor loading matrix are relatively larger factor loadings, it can effectively explain the principal components. As shown in TABLE IV, the first principal component is mainly composed of  $X_1$ ,  $X_3$ , and  $X_4$ , which reflects the impact of per capita GDP, research expense



investment intensity, and R&D expense investment on innovation capability. Its impact is more obvious. The second principal component is mainly composed of  $X_2$  and  $X_5$ , which reflects the proportion of scientific and technological appropriation in financial appropriation and the investment of R&D personnel. The variance contribution rate is smaller than the previous principal component, indicating that its influence on innovation ability is weak. The linear combination models of the corresponding indicators of each principal component are shown in (2) and (3):

**TABLE IV. Factor loading matrix**

INDICATORS	INGREDIENTS	
	1	2
PER-CAPITA GDP	.976	.183
PROPORTION OF SCIENCE AND TECHNOLOGY APPROPRIATION TO FINANCIAL APPROPRIATION	.612	-.683
RESEARCH AND EXPERIMENTAL DEVELOPMENT (R&D) INVESTMENT INTENSITY	.926	.265
R&D INVESTMENT	.939	.332
R&D PERSONNEL INVESTMENT	-.235	.909
THE NUMBER OF SCIENTIFIC RESEARCH ACHIEVEMENTS	.424	-.244

$$F_1 = 0.318X_1 - 0.001X_2 + 0.325X_3 + 0.345X_4 + 0.163X_5 + 0.057X_6 \quad (2)$$

$$F_2 = 0.009X_1 + 0.474X_2 - 0.045X_3 - 0.083X_4 - 0.562X_5 + 0.194X_6 \quad (3)$$

According to the principal component linear combination model, a comprehensive evaluation score function is constructed, as shown in model (4):

$$y = 67.82\%F_1 + 32.18\%F_2 \quad (4)$$

Putting the indicators into the above formula, the ranking and comprehensive evaluation results of the technological innovation capability of listed companies in Hebei Province from 2015 to 2020 can be got, as shown in TABLE V.

**TABLE V. Technological innovation capability ranking of listed companies in each year**

YEAR	$F_1$		$F_2$		y	
	SCORE	RANKING	SCORE	RANKING	SCORE	RANKING
2015	12.426	6	2.413	3	9.203	6
2016	15.728	5	4.349	1	12.065	5
2017	20.325	4	0.355	4	13.898	4
2018	32.783	3	3.397	2	23.326	2

2019	35.379	2	-2.395	6	23.224	3
2020	37.331	1	-0.761	5	25.073	1

From the ranking and Fig 10, it can be seen that the technological innovation capability of listed companies in Hebei Province has generally improved year by year. The speed increase was obvious from 2015 to 2018. Especially in 2018, Hebei Province carried out the reform of the science and technology reward system, focusing on improving the quality of rewards, raising the bonus standard, adding the "Enterprise Technology Innovation Award", and encouraging more enterprises to attach importance to innovation and development. Influenced by institutional reforms, in the same year, by increasing their R&D expenses and adjusting the proportion of R&D personnel, listed companies improved their own technological innovation capabilities, and drove the overall technological innovation capability of Hebei Province to achieve effective improvement.

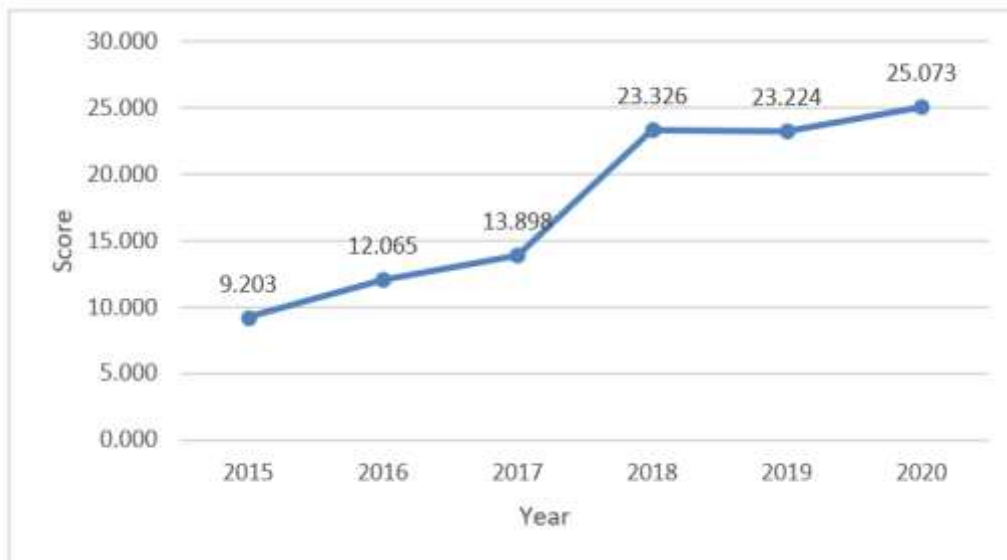


Fig 10: Technical innovation ability score of listed companies

## V. CONCLUSIONS AND SUGGESTIONS

Based on the above analysis, compared with the national level, the per-capita GDP of Hebei Province is relatively low, and the gap with the country persists and increases year by year, but the overall development trend is positive, and the GDP growth rate has increased; science and technology appropriations account for a relatively low proportion of financial appropriations, the change in the ratio is very gentle, and it has been floating around 1% for a long time since the "13th Five-Year Plan", which is quite different from the proportion of national science and technology appropriations in financial appropriations; the research and experimental development (R&D) investment intensity is weak, showing a rapid increase in development trend. Since 2018, the investment intensity has increased significantly, and the gap with the country has further narrowed; the R&D investment is still insufficient,

the average annual growth rate is low, and the growth process fluctuates frequently. The R&D investment of listed companies in the province is also low, but the growth rate is significantly higher than that of Hebei Province and the same period in the whole country; the input of R&D personnel is low, the full-time equivalent of R&D personnel is small, the fluctuation of personnel is large, and the overall trend is fluctuating and rising. The proportion of R&D personnel in listed companies in the province is relatively high and relatively stable; the number of scientific research achievements is small, and the innovation output is insufficient, however, the change in the number of valid patents is relatively good, and the growth rate is accelerating year by year. Through the comprehensive analysis and further analysis of the innovation environment, innovation input and innovation output, this paper believes that compared with 2015, the overall technological innovation capability of Hebei Province has improved, but there is still a large gap with the national level, and the technological innovation capability remains weak.

The improvement of technological innovation ability requires the joint efforts of the whole province. According to the analysis results, this paper, from the perspective of the government and enterprises, puts forward practical and effective suggestions for promoting the technological innovation ability of Hebei Province to a new height.

#### (1) Increase the gross domestic product

A good economic environment is the foundation and guarantee for the improvement of technological innovation capabilities. Limited by economic development, the investment in innovation funds in Hebei Province has been significantly insufficient in recent years. The government should seize the opportunity brought by the acceleration of Beijing - Tianjin - Hebei integration process to the economic development of Hebei Province, adjust and optimize the industrial structure, narrow the economic differences between counties, give priority to the development of central cities, use the radiation function of central cities to drive surrounding areas, and ultimately achieve overall efficient development of the regional economy.

#### (2) Introduce innovative preferential policies precisely

The current preferential policies for innovation introduced are not precise enough, they do not consider the needs of innovation entities in different periods and industries, and cannot fundamentally solve their problems. The government can refine the application conditions for preferential policies, combine with the characteristics of the capital market in Hebei Province and the industry distribution of enterprises, propose more targeted innovation preferential policies, and provide assistance to innovative but under-resourced businesses as far as the economic environment allows.

#### (3) Strengthen the awareness of high-level independent innovation

The company refuses to carry out independent innovation. In addition to the lack of its own funds

and other factors, whether the executives have the awareness of independent innovation is also one of the important factors that affect whether the company chooses to innovate or not. The company can increase the knowledge literacy of the senior executives, broaden their horizons, strengthen their awareness of independent innovation, and face innovation opportunities with a positive attitude by holding relevant lectures and encouraging senior executives to study. It is also possible to link innovation achievements with the performance of high-level individuals, and give rewards according to the number of achievements and the degree of completion of innovation, formulate innovation goals according to the industry situation, and adjust them in time to make the goals more suitable for the current enterprise situation, and motivate the senior management to work hard to improve the company's technological innovation.

#### (4) Optimize the allocation of human resources

The balanced and reasonable allocation of R&D talents is an indispensable guarantee for the company to improve its technological innovation capability and sustainable and stable development. The company should improve the technical level and scientific literacy of the recruited researchers through multi-channel and multi-form talent training, and vigorously promote the same high Cooperation and introduction of high-level technology and management talents, actively introduce leading technical talents urgently needed by the company, increase the daily assessment of researchers, reward researchers with outstanding performance in assessment, stimulate their innovation power, and improve the quality of the researchers' treatment in order to reduce the loss of excellent talents.

Research on driving factors and promotion path of technological innovation capability of enterprises in Hebei Province (21557609D), Research on the effect evaluation and promotion mechanism of innovation incentive policies for small and medium-sized enterprises under the new pattern of Double-circulation (21557608D), Special project for soft science research of Hebei Provincial Department of science and technology in 2021

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