Research on stimulating Mechanism of Innovative vigor of R&D Enterprises under the Background in Big Data

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Abstract: Innovation is the driving force for sustainable economic development, the core of economic growth, and an important driving force for world development. The construction and development of innovative vigor of R&D enterprises is an important part to accelerate the process of Chinese innovation process into an innovative country. The advent of the era of big data has brought new possibilities for R&D enterprises to enhance their innovative vigor. This paper explores the stimulating mechanism of innovative vigor of R&D enterprises in China under the background of big data, analyzes the current situation of innovative vigor of R&D enterprises in China, discusses the necessity of further stimulation of the innovative vigor of R&D enterprises under the background of big data, and puts forward practical suggestions for the obstacles faced by the stimulation of innovative vigor of R&D enterprises in China in combination with big data thinking.

Keywords: Big data; R&D enterprises; Enterprise innovative vigor; Performance assessment

1 Introduction

Under the background of "big wisdom moving cloud", the process of informatization of Chinese society and enterprises has been accelerated gradually, and big data technology has been born. Faced with the huge capacity and complex categories of big data, enterprises have sought digital transformation, especially R&D enterprises.

2 Literature Review

2.1 Enterprise innovative vigor

2.1.1 The connotation of enterprise innovative vigor

Scholars like Maquis[1](1969), Hansen[2](1997), HOLLAND M[3](1997), HOBDAY M [4](2005) , Richard[5](2006), MARY M C [5](2010), Zhang (2014), Wang (2017), Li (2022)carry out a great deal of research on the connotation of innovation. Scholars like Vicenzi [7](2000), Smith W S [8](2009), Zheng (2017)make an in-depth study on the connotation of enterprise vigor. Based on these research results, enterprise vigor refers to the ability of survival, sustainability and growth of an enterprise. Scholars mostly integrate the two concepts of "enterprise innovation"[9] and "enterprise vigor" and give connotations to enterprise innovation vitality, which can be roughly

MSIEID 2022, December 09-11, Chongqing, People's Republic of China

DOI 10.4108/eai.9-12-2022.2327594

divided into state view, capability view and revenue view.

2.1.2 The influencing factors of enterprise innovative vigor

The influencing factors of enterprise innovative vigor can be divided into exogenous factors and endogenous factors, as shown in the **Fig. 1**.

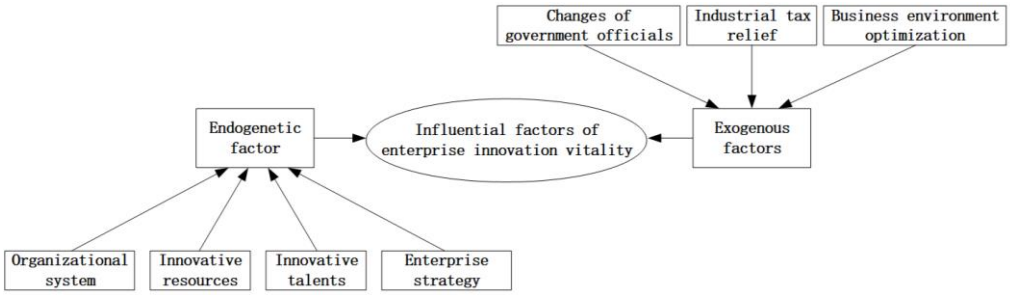

Fig. 1. Influential factors of enterprise innovative vigor

2.2 Big data application in enterprise innovation

At present, domestic and foreign scholars' research on the application of big data to enterprise innovation[10] can be classified into three aspects, as shown in the **Fig. 2**.

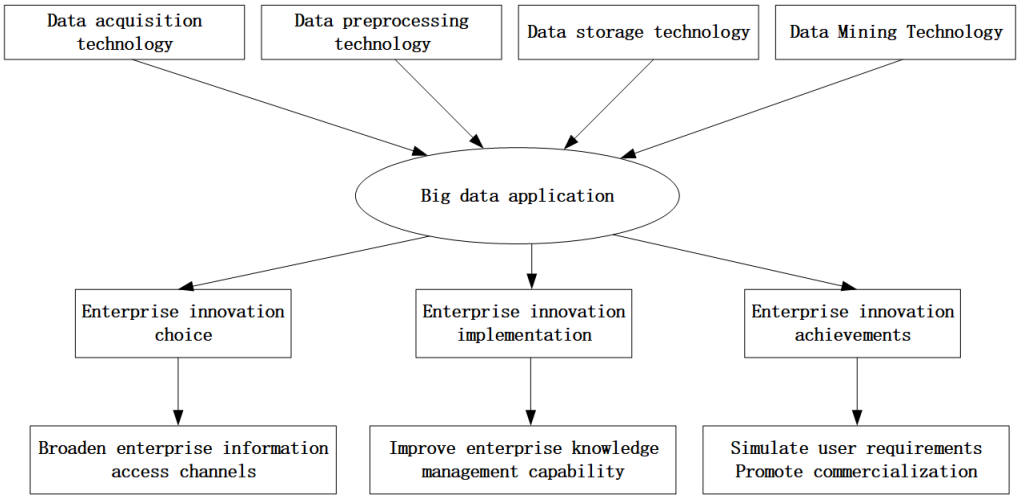

Fig. 2. Big data application in enterprise innovation

3 Construction of innovation vigor index system for R&D enterprises

In order to explore the development status of R&D enterprises, this paper selects the Electric Power Research Institute of State Grid Jiangsu Electric Power Co., Ltd (‘Electric Power Research Institute’ for short), a state-owned scientific research enterprise, as the research object.

3.1 Indicators selection for construction of innovation vigor index system for R&D enterprises

Adhering to the principles of systematizing, goal-orientation, scientific and operability, and based on the "Input Process Output" model, the innovation vigor index system of R&D enterprises is constructed from four dimensions, as shown in the **Table 1**.

Table 1. Innovation vigor index system for R&D enterprises

Level indicators	Secondary indicators	Description
Innovative resource vigor	The number of R&D staff	The number new quantity of R&D staff
	New innovation platform	The number of innovative platforms such as flexible teams, research institutes (offices), special scientific research and experiment classes, etc.
		The number of provincial and ministerial laboratories
	Industry-University-Institute Cooperation	Effect of technology R&D cooperation with scientific research institutes and high-tech enterprises, such as signing strategic cooperation agreements
		Increase in technology R&D cooperation projects with universities, external scientific research institutions, etc.
	R&D expenditure	Ratio of total R&D expenditure of the year to that of last year
		Total investment in results incubation
Innovative talent vigor	Annual completion of international expert training	The number of international experts trained
	Annual completion of national expert training	The number of national experts trained
	Annual completion of provincial and ministerial (industry level) expert training	The number of provincial and ministerial (industry level) experts trained
	Implementation of youth talent promotion project	The number of talents trained in the youth talent promotion project
	Operation quality of scientific research projects	Proportion of excellent evaluation in science and technology project acceptance
Innovative process vigor	Test capability improvement	Project investment quantity approved by provincial company
		Project investment amount approved by provincial company
	Think tank operation quality	Quantity of high-quality industry dynamic intelligence analysis
Innovative achievement vigor	New scientific and technological projects	Annual growth rate of scientific and technological projects undertaken
		Increasing quantity of high-level projects
	New intellectual property rights, high-level papers and monographs	Increase in intellectual property of leading business

	Increase in leading business papers and monographs
High level standards and specifications (especially leading international standards)	Number of leading international standards
	Number of leading national standards
	Number of leading industry standards
High level awards	Number of provincial and ministerial awards
Incubation and transformation of achievements	Total income from results incubation
	Number of new products incubated by achievements

3.2 Calculation of the weight of innovation vigor index system for R&D enterprises

3.2.1 Calculation of the level indicators weight

Make the $A_{m,n}(m = 1,2,3,4; n = 1,2,\dots,8)$ represent level indicators score respectively. Among them, m represents the number of level indicators: innovation resource vigor number "1", innovation talent vigor number "2", innovation process vigor number "3", and innovation achievement vigor number "4"; N represents the number of scoring experts.

Step 1: Sum the scores of the first level indicators by eight experts to obtain the sum value $S_n(n = 1,2,\dots,8)$, see equation 1.

$$S_n = \sum_{m=1}^{4} A_{m,n} \tag{1}$$

Step 2: Divide the score of all level indicators by the sum value $S_n(n = 1,2,\dots,8)$ obtained in step 1 and get the ratio $Z_{m,n}(m = 1,2,3,4; n = 1,2,\dots,8)$, see equation 2.

$$Z_{m,n} = \frac{A_{m,n}}{S_n} \tag{2}$$

Step 3: The average value of $Z_{m,n}(m = 1,2,3,4; n = 1,2,\dots,8)$ is taken as the weight W_m of the level indicators, see equation 3.

$$W_m = \frac{\sum_{n=1}^{8} Z_{m,n}}{8} \tag{3}$$

3.2.2 Calculation of the secondary indicator weight

Let $a_{m,b,n}(m = 1,2,3,4; b = 1,2,\dots,B; n = 1,2,\dots,8)$ represent secondary indicators score respectively. Among them, b represents the number of the secondary indicator under the level indicators. When m=1, B=4; When m=2, B=4; When m=3, B=3; When m=4, B=5.

Step 1: Sum the scores of the secondary indicators by eight experts to obtain the sum value $s_{m,n}(m = 1,2,3,4; n = 1,2,\dots,8)$, see equation (4).

$$s_{m,n} = \sum_{b=1}^{B} a_{m,b,n} \tag{4}$$

Step 2: Divide the score of all secondary indicators by the sum value $s_{m,n}(m = 1,2,3,4; n = 1,2,\dots,8)$ obtained in step 1 and get the ratio $z_{m,b,n}(m = 1,2,3,4; b = 1,2,\dots,B; n = 1,2,\dots,8)$,

see equation 5.

$$z_{m,b,n} = \frac{a_{m,b,n}}{s_{m,n}} \tag{5}$$

Step 3: Multiply the average value of $Z_{m,b,n}(m = 1,2,3,4; b = 1,2,\dots,B; n = 1,2,\dots,8)$ by the weight W_m of the corresponding level indicator as the weight of the secondary indicator, $w_{m,b}(m = 1,2,3,4; b = 1,2,\dots,B)$, see equation 6.

$$w_{m,b} = \frac{\sum_{n=1}^{8} Z_{m,b,n}}{8} \times W_m \tag{6}$$

According to the above weight determination method, this paper forms the weight table of the innovation vigor index system for R&D enterprises, as shown in the **Table 2**.

Table 2. the weight table of the innovation vigor index system for R&D enterprises

Level indicators	Weight of level indicators	Secondary indicators	Weight of secondary indicators
Innovative resource vigor	0.248	The number of R&D staff	0.059
		New innovation platform	0.060
		Industry-University-Institute Cooperation	0.061
Innovative talent vigor	0.253	R&D expenditure	0.068
		Annual completion of international expert training	0.064
		Annual completion of national expert training	0.064
		Annual completion of provincial and ministerial (industry level) expert training	0.064
		Implementation of youth talent promotion project	0.061
Innovative process vigor	0.225	Operation quality of scientific research projects	0.088
		Test capability improvement	0.067
		Think tank operation quality	0.070
Innovative achievement vigor	0.274	New scientific and technological projects	0.053
		New intellectual property rights, high-level papers and monographs	0.052

High level standards and specifications (especially leading international standards)	0.056
High level awards	0.057
Incubation and transformation of achievements	0.056

4 Calculation of innovative vigor index of R&D enterprises

4.1 Data pre-processing

Due to the large dimension difference between the acquired data, we need to first conduct dimensionless processing of the data to eliminate the error caused by the large dimension difference to the evaluation results. For indicator items whose base period data is not 0, We use the ratio of the current year value x_{mn1} to the base period value x_{mn0} as the dimensionless data x_{mnk}, see equation (7).

$$X_{mnk} = \frac{x_{mnk}}{x_{mn0}} \tag{7}$$

Among them, m (m=1, 2, 3, 4) represents the number of level indicators, n (n=1, 2, 3, …, 9) represents the number of secondary indicators, k (k=0, …) represents the based year and the nth year after the benchmark year. So X_{mnk} represents the dimensionless secondary indicators data of the m level indicators in year k.

For an indicator item with a base period data of 0, we add 1 to all the data of the indicator item and take the natural logarithm to eliminate the dimensional difference, see equation (8).

$$X_{mnk} = \ln(x_{mnk} + 1) \tag{8}$$

Among them, m (m=1, 2, 3, 4) represents the number of level indicators, n (n=1, 2, 3, …, 9) represents the number of secondary indicators, k (k=0, …) represents the based year and the nth year after the benchmark year. So X_{mnk} represents the dimensionless secondary indicators data of the m level indicators in year k.

4.2 Data calculation

4.2.1. Calculation of the secondary indicators

This paper takes 2019 as the benchmark year, and compares the data of 2020 and 2021 with the benchmark data of 2019. The data of other years are converted into relative values, see equation (9).

$$X_{mnk} = \frac{x_{mnk}}{x_{mn0}} \times 100 \tag{9}$$

Among them, m (m=1, 2, 3, 4) represents the number of level indicators, n (n=1, 2, 3, …, 9) represents the number of secondary indicators, k (k=0, …) represents the based year and the nth

year after the benchmark year. So X_{mnk} represents the dimensionless secondary indicators data of the m level indicators in year k, x_{mn0} represents the secondary indicators with the serial number of n under the m-th primary indicator in the base year.

4.2.2 Calculation of the level indicators

The weighted method is adopted to calculate the level indicators, see equation (10).

$$Y_{mk} = \sum_{n=1}^{M} X_{mnk} \times \beta_n \tag{10}$$

Where m (m=1, 2, 3, 4) represents the serial number of the level indicators; M (M=4, 4, 3, 5) represents the number of secondary indicators included in the level indicators (when m=1, M=4; when m=2, M=4; when m=3, M=3; when m=4, M=5); N (n=1, …, 5) represents the secondary indicator serial number; k (k=0, …) represents the base year and the n-th year after the base year; β_n represents the weight proportion of the corresponding secondary indicators. So X_{mnk} represents the secondary index data with the number n under the m-th primary index in year k, Y_{mk} represents the m-th level indicator of year k.

3. Calculation of the innovation vigor index

The four level indicators are weighted by the weighting method to comprehensively calculate the innovation vigor index of R&D enterprises, see equation (11).

$$Z_k = \sum_{m=1}^{4} Y_{mk} \times \beta_m \tag{11}$$

Where m (m=1, 2, 3, 4) represents the serial number of the level indicators, k (k=0, ...) represents the base year and the n-th year after the base year, β_m represents the weight proportion of the corresponding level indicators. So Z_k represents the innovation vigor index of R&D enterprises in year k. The final calculation results are shown in the **Table 3**.

Table 3. Innovation vigor index of R&D enterprises from 2019 to 2021

Year	Innovative resource vigor	Innovative talent vigor	Innovative process vigor	Innovative Achievement vigor	Index
2019	0.054	0.064	0.051	0.074	0.244
2020	0.052	0.095	0.052	0.093	0.293
2021	0.069	0.117	0.059	0.122	0.369

5 Challenges to further stimulate the innovative vigor of R&D enterprises

5.1 Focus on innovation achievements and ignore the innovation process

The existing performance appraisal system is more about the assessment of the results of

production innovations of researchers. On the one hand, the absence of innovation process evaluation of production researchers hinders the important role of in-process regulation in ensuring that innovation activities are implemented according to the established track, and on the other hand, reinforces the short-sighted tendency of performance appraisal mechanisms.

5.2 Lack of employee participation in the formulation of performance appraisal indicators

At present, most of the indicators involved in the performance appraisal system are selected by the leaders. On the one hand, it will enhance the subjectivity of the performance appraisal system, and the appraisers have more room to play, which to a certain extent weakens the objectivity and fairness of performance appraisal scoring. On the other hand, the performance appraisal system[10] with low employee participation cannot be well matched with the current production and scientific research tasks.

5.3 Focus on short-term indicators and lack of long-term orientation

The current performance appraisal system focuses on short-term indicators such as the level of research papers, the number of papers, and the number of patents obtained. It focuses on index innovation. Under this performance appraisal system, employees may leave the problems that can be solved in this year for next year in order to obtain higher performance scores to ensure the number of index innovations obtained in the next year, which is not conducive to the formation of a long-term innovation mechanism.

6 Countermeasures to stimulate innovative vigor of R&D enterprises

6.1 Strengthen employees' awareness of big data

Through data mining technology, employees of R&D enterprises can mine the existing product data, user feedback and other massive data to obtain potential product innovation points. They propose ideas in the established creative conference and spontaneously exchange different big data technologies with other employees in order to increase the possibility of creativity. R&D companies can evaluate the performance of employees in the innovation process by the conversion rate of ideas proposed by employees to further enhance innovation orientation.

6.2 Build a performance evaluation database system

Comprehensive use of big data technology and artificial intelligence technology to build an intelligent performance evaluation database evaluation system can improve the efficiency of scientific research performance evaluation. In addition, the intelligent performance evaluation database system empowers employee representatives from each department to develop performance evaluation indexes, decomposes the strategic objectives of R&D enterprises into individual departments and professional and technical personnel, and improves the understanding of production and R&D personnel on performance evaluation goals[12], thus better increasing employee participation in goal setting.

6.3 Strengthening Fault Tolerance Mechanism

In order to further encourage production and scientific research personnel to carry out long-term

innovation, it is necessary to establish and improve the fault tolerance mechanism for scientific innovation, such as the major innovation projects to cancel the compulsory acceptance, relax the production and scientific research personnel performance appraisal cycle. This will maximize the protection of the enthusiasm of the majority of production and research staff for entrepreneurship, that they can eat the "reassurance pill" and leave behind the bravado of their arms. In addition, R&D enterprises can use big data technology to analyze the similarity between the innovation results of this year's employees and the previous year's innovation results, reducing the similarity to strengthen the original innovation behavior of employees.

7 Conclusion

"The fundamental source of national scientific and technological innovation lies in people". R&D enterprises gather a group of scientific and technological workers, who are the important talent guarantee for implementing innovation-driven strategy and achieving technological self-reliance. The innovative vigor of R&D enterprises has a profound impact on the innovation vigor of China. In the era of big data, we should vigorously promote the technological innovation of R&D enterprises, speed up the development of core technology research ability, focus on the reform of science and technology system, and stimulate the innovative vigor of R&D enterprises and talents through the application of big data technology.

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