

Analysis of R & D Capability of China's Blockchain Technologies

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Abstract

As the pioneer of emerging technologies, China's blockchain technology-led enterprises are crucial to R & D capabilities. Through the collection of relevant data from 2015 to 2017, the input and output indicators were constructed; the DEA analysis method was used to evaluate the R & D efficiency, and the EM iterative algorithm was used for cluster analysis. The 15 companies were divided into three categories. It was found that the company's average pure technical efficiency was 0.68, and UFIDA's R & D investment was the largest. There were eight companies with input redundancy and insufficient output. There is a high degree of correlation between R & D scale efficiency and EM clustering results. If a firm is increasing in size or constant in scale, it is often classified as Category 2 or Category 3, otherwise it is classified as Category 1.

Keywords

Blockchain, R & D Capacity, EM Clustering, Efficiency

1. Introduction

The report on the work of the government, which has been delivered at the First Session of the 13th National People's Congress, pointed out that China's investment in research and development (R & D) has grown at an average annual rate of 11 percent, ranking second in the world in scale. The contribution of technological advances to economic growth has risen from 52.2 to 57.5 percent. Judging from the preliminary estimation results of Annual Report on Comprehensive Statistics of Science and Technology, National Bureau of Statistics of China issued on February 13th, 2018, in 2017, China's total R & D spending reached to 1.75 trillion yuan, while China's gross domestic product (GDP) 82.71 trillion yuan, then the R & D intensity (R & D/GDP) was 2.12 percent, increased

by 0.01 percent over the previous year. R & D expenses refer to the expenses for fundamental researches, applications and experimental development in the specified statistical year. It includes the labor cost, material fee, management fee and other related expenses used in the R & D process, and it can be used to reflect and evaluate the capacity for innovations and scientific research strength of a country. In 2017, the R & D expenses increased by 11.6 percent year on year, and the growth rate increased by one point compared with the previous year. From the perspective of the whole world, the total amount of R & D investment in China now ranks the world's second after the United States. Since the 18th National People's Congress of China, R & D investment is on a continuous up-trend. The R & D intensity from 2014 to 2016 was 2.02 percent, 2.05 percent and 2.11 percent respectively. The most noteworthy R & D investment is the fundamental research, which refers to the underlying research to explore the basic principle of phenomena and facts, and to research experimentally and theoretically on possible new knowledge. China's fundamental research funding in 2017 was 92 billion yuan, registering year-on-year growth of 11.8 percent, and its share in the total R & D expenses had grown to 5.3 percent, up from 5.2 percent. Nevertheless, the proportion is not big in general. R & D activities mainly include universities, enterprises and research institutes, among which enterprises are the biggest contributors. The comprehensive R & D funding was 1.37 trillion yuan in 2017, registering year-on-year growth of 13.1 percent, and maintained a double-digit growth for two years straight; The R & D funding of the high-efficient and scientific research institutions was 0.24 trillion yuan and 0.11 trillion yuan, registering year-on-year growth of 7 percent and 5.2 percent respectively.

The report, delivered at the 19th National People's Congress of China, pointed out that the concept of "innovation" involved in the Party's theory, practice, system, culture and other aspects. The world is changing, we must firmly commit innovation-driven development strategy. Innovation is not limited to certain areas, but usually combines with science and technology. As the report emphasizes, the principles and policies of country's innovative construction must focus on the theme of the development of science and technology.

But in recent years, many enterprises focus on exploration of emerging technologies blockchain technology and have carried on development strategic plan in order to positively respond to the national policy of innovation and development. The Organization for Economic Cooperation and Development (OECD) published the Scientific and Technological Innovation Outlook in 2016, in which the report listed the top-ten hot spots of future technology development, including blockchain technology [1]. In October 18th, 2017, the ministry of industry pointed out that financial services will be blockchain's first field for application, due to its high reliability, simplified process, easily-tracked transaction, data quality improvement and other characteristics. And blockchain can be applied to the financial payment, clearing and settlement, asset management, security

trading, identity, credit, etc. In May, 2016, the publication of the domestic book, *Blockchains: Define the New Pattern of Future Finance and Economy* [2] thoroughly pushed “blockchain” to public’s view, and what differences blockchain technology has brought to future finance, and economy was introduced in detail in this book.

Blockchain is an emerging decentralized architecture and distributed computing paradigm underlying Bit coin and other crypto currencies, and has recently attracted intensive attention from governments, financial institutions, high-tech enterprises, and the capital markets. Blockchain’s key advantages include decentralization, time-series data, collective maintenance, programmability and security, and thus is particularly suitable for constructing a programmable monetary system, financial system, and even the macroscopic societal system. The birth of blockchain is inseparable from bitcoin. The former is the underlying technology and infrastructure of the latter, but the latter is just an application of the former. Blockchain, which was introduced by the founder of the currency Satoshi Nakamoto after the financial crisis, originated from the foundation of society and can be simply described as a decentralized and trustless way to safeguard the distributed database jointly. Blockchain is an essentially common database to record and update transactions.

The blockchain technology has been promoted for less than 10 years, but it has aroused great attention. Especially in last two years, blockchain has gradually become an independent innovation hot point. It creating a new distributed data storage technology with an innovation change on system/program design. Maybe, it will subvert the organizational model of current business community in future. So, it received more and more attention from Business and Technology communities. Many practitioners have made new explorations in combination with their fields. Finance is a high frequency field of science and technology innovation, which has a better perception and response ability of blockchain technology than others, and the advantages of its own capital ensure that it has enough strength in the new technology and can be applied to financial practices. Postal Savings Bank of China and International Business Machines Corporation (IBM) announced a cooperation on blockchain technology. Hundreds of transactions had been concluded since the system was launched on October, 2016.

The specific objectives of this study are 1) to analyze R & D efficiency of blockchain technology leading enterprises and 2) to analyze input and output indexes of blockchain of each listed company. And the rest of the paper is organized under four sections. Section2 discusses the development and application of blockchain by reviewing the literature. Objects and data used in this study are presented in Section 3. The preliminary and empirical results are captured in the Section 4. Section 5 provides the conclusion and implication of the findings.

At present, although there are many commercial products using blockchain technology, but the basic theory and technology research are still immature and not conducive to the long-term development of the blockchain technology. This

paper conducts theoretical and empirical research on the technological innovation ability of China's blockchain technology service providers, hoping to provide references and inspiration for future researches.

2. Theoretical Background

Since the history of blockchain technology is not long and the relevant research results are not many, domestic and foreign researches mainly focus on the principle and practice of blockchain technology.

Foreign researches start relatively earlier and are more mature, most of which use currency as starting point for research and discuss how to apply digital encryption on currencies. Moreover, they also attach great importance to the study of blockchain technology application scenarios. One of the earliest researches by Satoshi [3] claim that blockchain technology is the underlying technology and the foundation of Bitcoins technology, mainly for encrypting data structure and transmission and realizing the mining and trading of Bitcoins. Lewis [4] vividly compares the blockchain technology to a public ledger, which is not independently owned but can be widely spread and shared, whereas Chris [5] emphasizes on the aspects of practical application. He believes blockchain will promote the development of financial technology, and at the same time, it will be the instrument of political and social transformation. He also believes it is full of infinite possibilities to commercialize the blockchain, which will make a significant contribution to set up a decentralized world. Swan [6] divides the application fields systematically into monetary, financial and non-financial aspects, and focuses on the social science research of blockchain technology. Moser *et al.* [7] design a set of customized application frameworks for the application of financial field, and emphasize the advantages of using blockchain technology, such as high security, high elasticity, high resistance to the attack of a higher degree and so on. Meanwhile, some scholars have discussed the blockchain technology from different aspects, such as intelligent contract, privacy protection, security and so on. Bigi *et al.* [8] prepare an agreement after the optimum organization of formalized models and game theory. This agreement can distribute intelligence so that it is a method with a great development prospect and the value of further research and development. Mougayar *et al.* [9] comprehensively analyzed Bitcoins using blockchain as the fundamental technology, and found security bugs. Mougayar also analyzed its trend and put forward corresponding countermeasures and suggestions.

Compared with foreign countries, the domestic researches are slightly insufficient, especially researches of the fundamental theory, and scholars usually focus on the selection and discussion of practical application path. Zhang Bo [10] summed up relevant experience according to the application of blockchain technology in foreign financial industry, and believed that it could reduce financial risk, especially credit risk. Zhang Rui [11] analyzed the comprehensive influence of blockchain technology on the development of financial industry and

considered that the effect was subversive. Xian Jingchen [12] suggested that “blockchain technology +” will produce a series of catalytic effects, such as reducing trust cost, real-time accounting, optimizing the structure of big data, etc. Lin Xiaoxuan [13] believes that the development of blockchain technology and financial industry will achieve a win-win situation and energize China’s Internet industries. However, some scholars have questioned the security, privacy and compliance of blockchain technology. Chen Yixi [14] suggested that high efficiency with low energy, high security and decentralization can’t be satisfied at the same time, all of which form an unstable triangle, so there may be big potential safety hazards after a wide promotion of the blockchain technology. Li Lihui [15] pointed out that Banking Regulatory Commission needs to pay special attention to the huge impact on the financial risks blockchain technology brought, and must supervise effectively at technology while establishing laws and regulations. Wei Changjiang, Jiang Runxiang [16] summarized that current bondages and restrictions in the development of blockchain come mainly from the concept aspect and legal aspect, and at the same time from a competitive technical challenge. They suggested that there is still a need to overcome the existence of technology hitting a plateau and the future is not very clear. Han Feng [17] believed that the most important thing for blockchain to achieve is the establishment of the basic agreement, which involves the basis of global mutual trust. Zheng Yao [18] pointed out that although the blockchain technology has many uncertain factors, but it does bring good opportunities for the development of the banking industry. Despite still many problems to solve, more and more scholars have carried on useful attempts. Yang Huiqin [19] used blockchain technology as the core to build a supply chain information platform with mutual trust and win-win situations and provided a new way for automobile supply chain.

By sorting out and summarizing the above researches, we will find that most scholars have positive expectations and certain concerns for blockchain technology, and they are keen to apply this technique to actual business. But few scholars choose to study the science and technology innovation ability of the current blockchain technology service provider in China, so our researches will help to understand future competitive advantages of blockchain technology in our country.

3. Blockchain Technology Leading Enterprises

Technology is constantly improving, and in the near future blockchain technology will provide customers with more modern services. However, it is an indispensable condition in reality that although more and more financial institutions focus on the application of blockchain technology, they do not have the core, just to apply a new tech. For this emerging technology, the innovation ability of blockchain underlying technology service providers is about whether financial enterprises can get sufficient technical supports in the process of innovation. For

example, Postal Savings Bank of China is cooperating with IBM to carry out scientific and technological innovation instead of seeking a proper domestic technology service provider. For the emergence of a technology, commercial companies often have two choices, one is the development and improvement of the underlying technology, and the other is the development and promotion in the application layer. The former is very difficult. In the case of non-open source technology, many technicians often have to give up, not even have the opportunity to imitate. However, it is relatively easy to apply, using the underlying technology that has been produced before to design, frame and implement according to their own ideas. For example, many applications (APPs) became popular in capital market. What capital parties value most is not the design of the program itself, but the customer value and future business potentials behind. The underlying technology of APP development and application is often some abroad underlying programming language, such as C, Python, Java, etc., while the domestic research team is in the application layer to conduct on the basis of the code. In addition, the production and prophase investment of underlying technology are very large, but the development cycle in application layer is often shorter, faster in rewards, able to meet the marketing demand in time in accordance with the requirements of the business plan for high frequency modification and debugging. Therefore, without sufficient technology strength and innovation ability, it is difficult to achieve a major technological breakthrough.

By the end of April, 2017, there are 1230 blockchain enterprises in the world, and China and Europe are in the leading positions. "Blockchain: from Digital Currency to Credit Society" [20], summarizes 52 blockchain projects in China in the appendix. Most blockchain enterprises are located in developed cities such as Beijing, Shanghai, Hangzhou Guangdong and etc. Matrix finance companies are positioned as underlying applications, whose financing amount for A round is 150 million from Wanxiang Group. Other companies also receive a different number of financing amount, which overall is not very high, and most are less than 10 million yuan. Generally speaking, companies balancing or focusing on the underlying technology development are more popular with the investment institutions, the total financing amount of which are 458 million yuan.

With a new technology from birth to constant improvement to commercial applications, creating profits often require a long process. Especially fierce competition in the information age today, the prophase development process often needs a lot of money, which is usually a common short board of initial venture companies. However, many listed companies with vision and investment strategy will choose to diversify their operations and choose to track investment in blockchain technology in order to obtain good returns in the future. Or there are some listed companies that are mainly engaged in the peripheral business of blockchain and will increase the development of blockchain technology in the case of national encouragement policy and market demanding stimulation. Therefore, it is possible to understand the R & D investment and R & D effi-

ciency of the blockchain technology in China through the R & D scale of all current blockchain listed companies.

For which the listed company should be incorporated into the concept of blockchain, different financial information terminal will give different results, for example, blockchain plate of Wind contains 15 companies including Guang Bo Group, Heng Bao, GRG Banking Equipment, while blockchain plate of iFinD contains 21 companies including First Capital Securities, Yuan Guang soft, Kingdom Sci-Tech. iFinD contains 6 companies more than Wind.

According to the terminal market share of the domestic financial situation, Wind has a major share, whose software license purchase price is also the most expensive, and there are also Hundsun Ju Yuan, Fin china Financial Big Data, Tian Xiang, Hong Kong and Macao information, Genius Finance and so on. In addition, considering the authenticity and convenience of obtaining the data, the 6 unselected enterprises did not release the data related to R & D in their annual financial reports, which brought great difficulties to the data collection. Therefore, the 15 blockchain listed companies are finally selected into the R & D efficiency and cluster analysis, and the specific list is shown in **Table 1**.

Table 1. Details in blockchain technology leading enterprises in wind terminal^a.

Stock Code	Abbreviation of Securities	Abbreviation of Companies	Number of Employees	Registered Capital (billion yuan)	Province	Keyboard Attributes
300377.SZ	Ying Shisheng	YSS	1539	7.4238	Guangdong Province	Private Enterprise
300468.SZ	Sifang Jingchuang	SFJC	1707	1.0537	Guangdong Province	Private Enterprise
300130.SZ	Xin Guodu	XGD	1513	2.6516	Guangdong Province	Private Enterprise
600446.SH	Xin Zheng	JZGF	5735	8.3501	Guangdong Province	Public Enterprise
002103.SZ	Guang Bo	GBGF	2460	5.4921	Zhejiang Province	Private Enterprise
002537.SZ	Hailian Jinhui	HLJH	4218	12.5135	Shandong Province	Private Enterprise
600570.SH	Hundsun Dianzi	HSDZ	6829	6.1781	Zhejiang Province	Private Enterprise
600797.SH	Zheda Wangxin	ZDWX	4773	10.5599	Zhejiang Province	Other Enterprise
002152.SZ	Guangdian Yuntong	GDYT	21,311	24.2889	Guangdong Province	Local State-owned Enterprise
002177.SZ	Yu Yin	YYGF	396	7.6119	Guangdong Province	Private Enterprise
002104.SZ	Heng Bao	HBGF	1413	7.1203	Jiangsu Province	Private Enterprise

Continued

002268.SZ	Wei Shitong	WST	2092	8.3834	Sichuan Province	Central State-Owned Enterprise
300386.SZ	Feitian Chengxin	FTCX	946	4.1804	Beijing	Private Enterprise
300465.SZ	Gao Weida	GWD	2984	4.5038	Beijing	Private Enterprise
600588.SH	Yongyou	YYWL	14,037	14.6422	Beijing	Private Enterprise

a. Source: Wind.

According to the actual data and **Table 1**, the establishment date of the 15 listed companies was between 1992 and 2004.8 companies were established before 2000, and the remaining 7 were founded in the 21st century. The average number of employees is 4797, the lowest is YYGF and the largest is GDYT, followed by YYWL. The average of registered capital is 833 million yuan, the standard deviation is 5.66, the standard deviation coefficient of 68.02%, and full range is 2.324 billion yuan, all of which show that the distribution of registered capital of 15 companies is not centralized, and there is a big difference and a low representative average. The largest number of listed companies are in Guangdong province, followed by Beijing and Zhejiang province. In addition, Guiyang is a city who has a relatively mature big data industry, but Guizhou, a province in which it belongs, has not appeared in the blockchain plate. Only two of the 15 companies are state-owned: GDYT and WST, and the remaining 13 are privately owned.

If we analyze the management scope of the 15 listed companies carefully, we will find that only 2 companies are not based on computer or financial hardware and software. Management scopes of the remaining 13 cover the following items: electronic equipment manufacturing, computer application system and the development of supplementary equipment, import and export of technology, ticket machines, electronic products, bank card electronic payment terminal products, certificates, bills, password envelopes, smart tags, intelligent terminal, the commercial password products approved by China's Password Administration Institution, system integration, communication and information security, Internet data and so on. Taken together, most of the above blockchains technology of listed companies have a certain business and technical basis. Because essentially, the blockchain technology is software development, containing many computer technologies such as tickets, account books, distributed database, and its application in domestic for the first time is in financial filed. All listed companies with financial terminal services experiences also joined in the R & D team. As a result, we can argue that although the above companies are not professional software development companies, but they have a positive effect on R & D of blockchain and blockchain has been integrated into their development strategies.

Executives of GDYT adhere to the concept of “pre-research, development, and the promotion” and organize a work team of doctors to actively develop blockchain technology and pay close attention to the information on the digital currency. YSS found a chain stone company, which aims to establish new financial fundamental services to achieve a simpler and more efficient situation in the supply chain of finance, investment management and other fields. SFJC with IBM has established a blockchain cooperation relationship to jointly develop the cross-border financial high-tech application products. XGD is actively promoting the development of blockchain technology and constructing a closed-loop ecology in electronic payment. ZDWX bought a company recently, which is committed to build national-independent blockchain platform, With the sales and operation of ATM machines of YYGF, the team is studying the application opportunities of blockchain technology in information security and identification field to improve safety and efficiency. HBGF says it has a certain reserve on the blockchain technology, focusing on information security, data exchange, and has already pushed the project into the application stage, so it is with WST. While FTCX believes that their products belong to terminal auxiliary products in the blockchain, and the market with great uncertainty. GWD has deep business and talent accumulation in the paper market, and it has made relevant layout in application. YYWL made a strategic investment of science and technology on CXKJ to obtain a 21.03% share. CXKJ is an innovation company that located in development and application of blockchain technology.

4. Analysis of Innovation Ability

4.1. Analysis of R & D Efficiency

R & D is the source of innovation, the precondition of transforming scientific results. Block chain, as an emerging technology, will become a thing that the listed company will compete for. Through the analysis of R & D input and output of each company in near five years, we can objectively understand a company's research strength, and analyzing its R & D efficiency can reflect the achievement transformation ability.

We choose the most popular method, Data Envelopment Analysis (DEA), to evaluate the efficiency of R & D. Zhang Yuqing [21] introduces the DEA method is a nonparametric evaluation method based on the evaluation unit which has already been introduced by A. Charnes, W. W. Cooper in 1978. Two indexes (output and input) are represented in **Table 2**.

The R & D expenses and operation revenue in **Table 2** are collected from the financial reports of the companies in 2015 and 2016 and the financial reports in 2017. The number of technicians in R & D is calculated from the average data of 2015 and 2016. The statistical time of the number of applied patents and number of published patents is from 2015 to 2017, which should be explained in particular that in the calculating process of the listed companies' patents, some is 0. And this will be replaced by querying and summing up the number of

Table 2. Input and output index system of blockchain technology leading enterprises^a.

Abbreviation of Companies	Input Indexes		Output Indexes		
	R & D Expense (million yuan)	Number of Technicians in R & D	Number of Applied Patents	Number of Published Patents	Operation Revenue (million yuan)
YYWL	2524.63	4392	176	223	11756.93
HSDZ	2421.94	3889	34	94	5475.99
GDYT	847.17	1093	419	478	9926.54
JZGF	951.58	2668	1	2	8118.27
ZDWX	356.08	792	12	15	10613.49
HBGF	364.91	476	102	109	3832.82
WST	454.22	604	64	99	3967.11
XGD	345.29	440	104	115	2609.36
FTCX	273.68	418	333	415	2206.99
YYGF	226.51	196	76	91	2161.89
YSS	303.02	991.5	14	14	796.53
SFJC	160.32	433	1	1	864.72
GWD	159.57	205	3	3	2439.38
GBGF	49.65	159	1	1	4183.05
HLJH	158.36	477	74	75	6388.60

a. Source: Wind; iFinD; Bai Teng.

patents of its 100% owned subsidiaries.

Among them, JZGF announced a patent in 2015. The number of patents filed by royal bank of China holding from 2015 to 2017 was 76, and the number of patents of YYGF was 91. YYGF Will declare 5 patents from 2015 to 2017, and 5 patents will be announced. The number of patents declared by HLJH from 2015 to 2017 is 76, and the number of patents announced is 91. GWD reported 3 patents from 2015 to 2017. The number of patents filed by ZDWX from 2015 to 2017 is 12, and the number of patents announced is 15. However, after such calculations, there are still some companies whose patent applications and publications are 0. In order to carry out DEA analysis, they are assigned a value of 1 and add 1 to all other companies' corresponding projects.

It can be seen from **Figure 1**, the median in R & D expenses of YYWL is the largest, which of GBGF is the smallest. Moreover, the R & D expenses of HSDZ is second to YYWL. In the boxplot, the position of YYWL's box body is the highest, and the horizontal line between the lower quartile and the upper quartile represents the position of the median, indicating that its R & D expense is relatively highest. Similarly, GBGF is the smallest. But its inter quartile range is the largest with the longest box body. Combining with concrete data, it shows a geometric average growth of 26.09% in 2012-2016.

The largest growth of R & D expenses can be seen in JZGF, from 1.1186

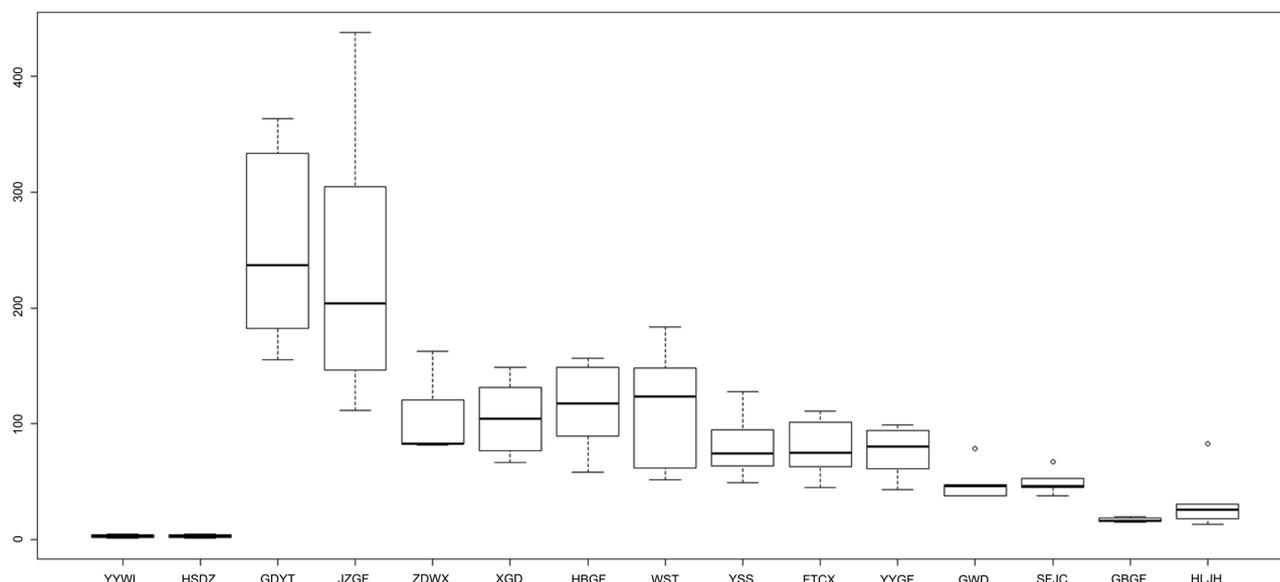


Figure 1. Boxplots of R & D expenses of blockchain technology leading enterprises in 2012-2016.

million yuan in 2012 to 4.3766 million yuan in 2016, and the smallest is GBGF. In general, all the listed companies' R & D expenses are increasing constantly. It was the critical period for the blockchain technology in 2015 and 2016, only the R & D expenses of ZJWX decreased by 41.44 million yuan in 2016 compared to 2015.

After using deap to deal with the data, we get the results in **Table 3**, calculation of mean of each efficiency is: 0.653, 0.820, 0.781. The purely technical efficiencies of YYWL, GDYT, ZDWX, FTCX, YYGF, GBGF and HLJH are all 1.

From **Table 4**, we can learn that company that has an insufficient output is XGD, and companies with both insufficient output and redundant input are HSDZ, JZGF, HBGF, YSS, SFJC and GWD. If the purely technical efficiency of listed companies is 1, but the scale efficiency is less than 1, it means that there is no need to reduce the input and to increase the output. The overall efficiency of listed companies is not effective, because of its size and mismatching of input and output, which means that it need an increase or a reduction in the size, for example, GDYT and ZDWX need a reduction in the size.

4.2. Cluster Analysis of Expectation Maximization

The Expectation Maximization (EM) Algorithm is an iterative algorithm [22], which is used for the maximum likelihood estimation of the probabilistic model parameters of implicit variables. Each iteration consists of two steps: E step for expectation; M step for maximum value. EM algorithm is widely used in cluster analysis, machine learning and other fields. For E step, to calculate the probability of each cluster as weight: if a large point is possibly belonging to a cluster, then it will be set a corresponding probability close to 1. And for that there might be a point belongs to two or more clusters, it needs to establish a probability

Table 3. DEA efficiency evaluation of blockchain technology leading enterprises.

Abbreviation of Companies	Overall Efficiency	Purely Technical Efficiency	Scale Efficiency	
YYWL	0.142	1	0.142	drs
HSDZ	0.073	0.092	0.79	drs
GDYT	0.728	1	0.728	drs
JZGF	0.116	0.249	0.464	drs
ZDWX	0.522	1	0.522	drs
HBGF	0.519	0.538	0.965	drs
WST	0.381	0.398	0.957	drs
XGD	0.462	0.521	0.887	irs
FTCX	1	1	1	-
YYGF	0.806	1	0.806	irs
YSS	0.065	0.193	0.338	irs
SFJC	0.078	0.367	0.212	irs
GWD	0.464	0.78	0.595	irs
GBGF	1	1	1	-
HLJH	0.819	1	0.819	drs

Table 4. Slack variables of input and output indexes of blockchain technology leading enterprises.

Abbreviation of Companies	Input Indexes		Output Indexes		
	R & D Expense (million yuan)	Number of Technicians in R & D	Number of Applied Patents	Number of Published Patents	Operation Revenue (million yuan)
YYWL	0	0	0	0	0
HSDZ	9.887	0	48.462	0	0
GDYT	0	0	0	0	0
JZGF	0	118.606	6.732	7.568	0
ZDWX	0	0	0	0	0
HBGF	62.985	0	0	16.597	0
WST	61.067	0	16.703	0	0
XGD	0	0	0	12.749	205.013
FTCX	0	0	0	0	0
YYGF	0	0	0	0	0
YSS	0	22.02	0	3.211	3309.144
SFJC	9.22	0	0	0	3318.33
GWD	70.166	0	0	0.4	1689.772
GBGF	0	0	0	0	0
HLJH	0	0	0	0	0

distribution of clustering. So, EM algorithm has a feature, there is no strict rules that one point must belong to one cluster. For step M, the weight is used to calculate the estimate the parameters of each cluster (mean and variance): each data point uses a probability from E-step as its weight, then we calculate means and variances of each cluster, and then calculate the overall probability or maximum likelihood clustering. In this way, it is possible to increase the total logarithmic likelihood through E-step and M-step until convergence, and the maximum value is likely to fall into local optimum, so multiple iterations are required.

By using Mclust packages of R and writing codes [23] [24] [25], we analyzed input and output indexes of blockchain of each listed companies, and got the classification results: the total can be divided into three categories, the number of companies followed by 6, 5, 4, the value of maximum likelihood estimate is 440.50, Bayesian Information Criterion (BIC) value is 1027.24, ICL value is 1027.24.

BIC in **Figure 2** is a measure of model fitting degree and complexity. The larger this value is, the worse the fitting degree is. When the sample is divided into three categories, BIC value is the smallest.

Therefore, from **Figures 2-4**, we can know that:

Category 1 contains: YYWL, HSDZ, GDYT, JZGF, ZDWX, HLJH;

Category 2 contains: XGD, HBGF, YYGF, GWD, GBGF;

Category3 contains: WST, YSS, FTCX, SFJC.

5. Conclusions and Implications

Through the above analysis, we find that YYWL is the strongest power company,

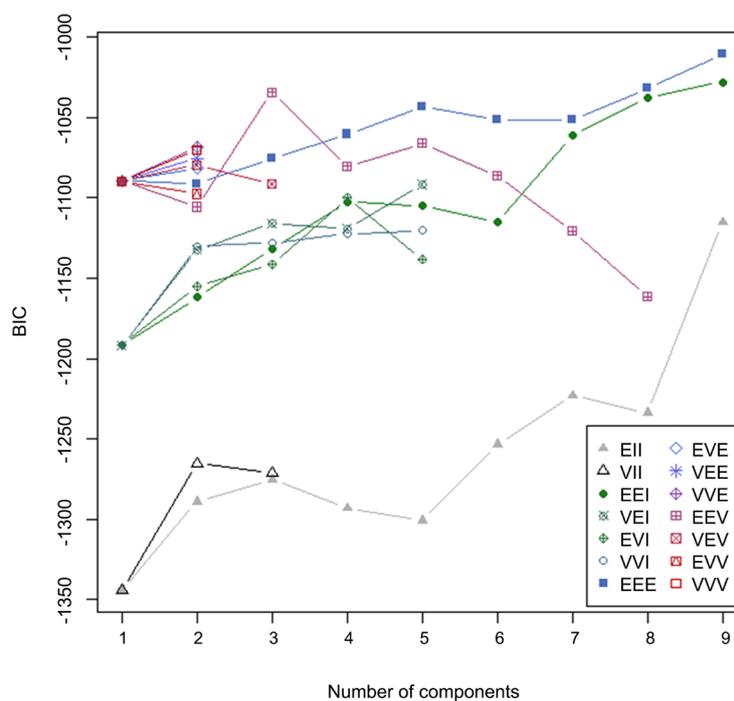


Figure 2. BIC values of cluster analysis of EM.

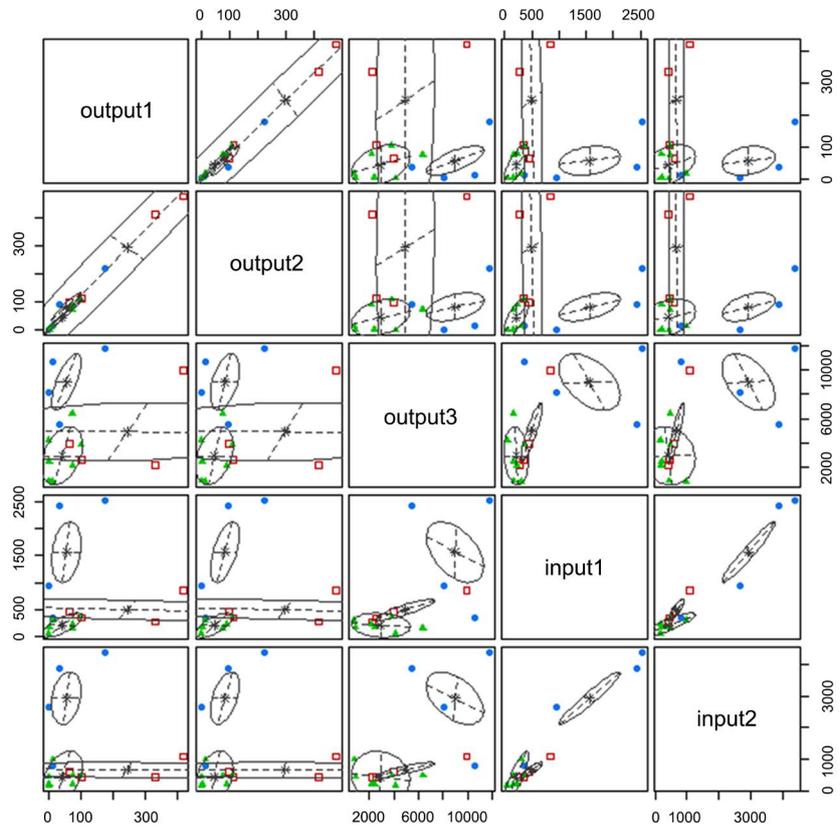


Figure 3. Classification chart of cluster analysis of EM.

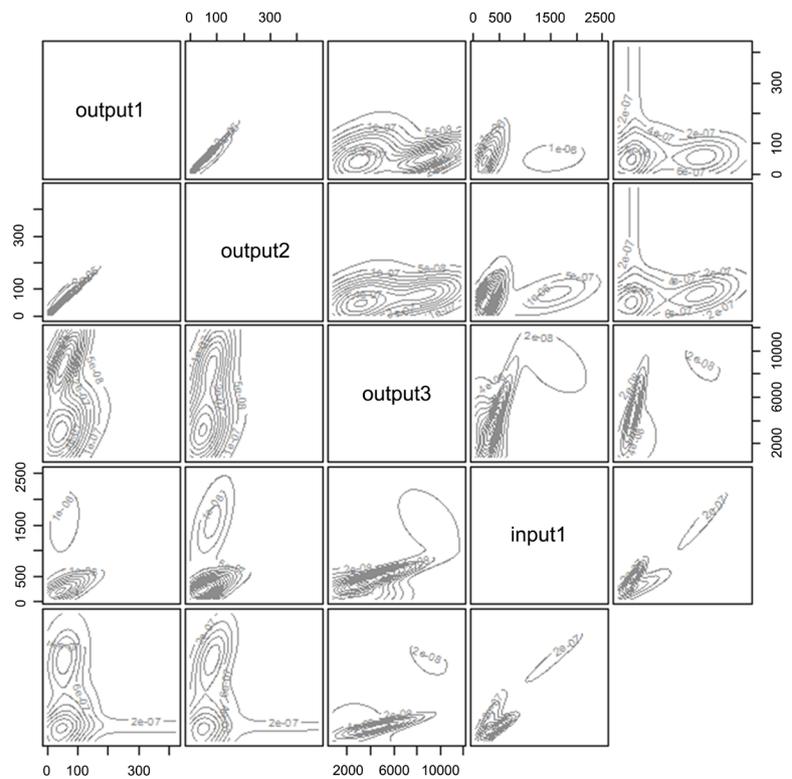


Figure 4. Density map of cluster analysis of EM.

which is not only with a largest R & D expenses, an effective purely technical efficiency, but also no input redundancy or output deficiency. Although R & D expenses of HSDZ is large, it has a redundant investment and insufficient output, and the purely technical efficiency is very low. Among the 15 blockchain listed companies, only 7 companies have no redundant input and insufficient output, and the pure technical efficiency is 0.68 with 0.32 to improve. In addition, by combining the results of R & D efficiency and EM clustering analysis, it can be seen that there is a high correlation between R & D scale efficiency and EM clustering results. If a company is under increasing or constant returns to scale, it is often divided into category 2 or category 3. If it is under decreasing returns to scale, it is often divided into category 1.

Blockchain technology is currently in a crucial period, all the above companies must accept high risks, even no returns while seizing development opportunities. Therefore: 1) Hi-Tech Industry tends to be in the hands of a few technicians, so that enterprises should formulate personalized talent introduction system, meet the requirements of people on welfare as far as possible under the condition of an adequate budget. 2) Blockchain technology needs to be combined with business for commercial use intime, otherwise, it is easy to face the problem of funds shortage, which leads to the failure of the research. (3) The security of developed technologies and the research results should be strengthened to prevent leakage and theft.

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