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Construction and Analysis of Enterprise Innovation Capability Evaluation Model – A Case Study of 30 Listed Companies in Gansu Province

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Abstract. Listed companies are the backbone of the regional economic growth. The enterprise innovation capability is the ability of the enterprises to integrate the internal and external resources through multi-dimensional innovation activities to improve the enterprise performance and obtain the economic benefits in a short period. This paper constructs the evaluation index system and evaluation model of enterprise innovation ability from three perspectives: technological innovation ability, institutional innovation ability and management innovation ability, and uses the improved AHP method to determine the weight of each index. Based on the data of 30 listed companies in Gansu Province from 2016 to 2020, this paper measures their innovation efforts and suggests the ways to improve their innovation ability.

Keywords. Listed companies in Gansu Province, Evaluation of innovation ability, Improved analytic hierarchy process

1. Introduction

For a country or a region to achieve leapfrog development, the key lies in using technological innovation to achieve the economic growth and sustainable development. Marx and Schumpeter emphasized innovation at the center of the economic growth theory in 19th and 20th century respectively[1]. Chris Freeman (1971), a British economist, believed that innovation refers to the introduction of technology, design, production, finance, market, management and many other steps involved in a new product or process for the first time[2]. Schumpter (1912) regarded innovation as the implementation of new combinations of factors and conditions of production[3]. Mansfield (1971), in his "technology extension theory", believed that innovation as such is an invention or the first application of technological changes in the existing products in furtherance of business activities[4].

Mensch, a German-American economist, believed that innovation refers to the application of technological progress in economic development[5]. The diffusion of

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technological innovation and the application of new products and technologies boost the national economy as a whole. When the technology deadlock occurs, the economy may stagger or even decline.

Clarifying the dominant position of enterprises in scientific and technological innovation is the fundamental way to improve the independent innovation ability of the enterprises. Rammer's (2011) empirical analysis of the German manufacturing industry proved that a large number of enterprises without technological innovation have lower economic income than those with technological innovation[6]. The empirical analysis of large American enterprises (Cohen, 1987)[7], Spanish enterprises (Galende and Suarez, 1999)[8] and European enterprises (Arundel, 2008)[9] also corroborated that the technological innovation ability is not the only source for enterprises to obtain competitive advantages. Enterprises having no R&D even exhibit higher productivity and economic benefits than the R&D enterprises (Kimer, 2009)[10], which poses an important challenge to the traditional innovation theory that “enterprises without R&D or low technological innovation rate mean stagnation or even recession”. At the same time, the priority given by the economists to the technology innovation strategy points out a very important fact that although the environment or system is similar, but because of the niche business belonging to different areas, the innovation of the enterprise strategic activities in multiple dimensions show obvious heterogeneity indicating that the enterprise innovation ability should be diversified.

Since 1990s, researchers have further supplemented the connotation of enterprise innovation, making it no longer limited to technological innovation. Chang Huize (1994) believed that enterprise institutional innovation and technological innovation are interrelated and mutually promoting[11]. Institutional innovation in a narrow sense is organizational innovation, mainly referring to the enterprise property rights system. Japanese scholar Ikujiro Nonaka et al. (2006), in their book “Enterprises That Create Knowledge: The Driving Force for Continuous Innovation of Japanese and American enterprises” emphasized that the Japanese and United States enterprises are involved in the dynamics of continuous innovation and proposed a theory of enterprise sustainable innovation, pointing out that the fundamental task of these companies is continuous introduction of enterprise innovation, and management of institutional projects[12]. They further pointed that it comprises a variety of innovative enterprise innovation ability and project cluster dynamic nonlinear complex process of system integration. In the investigation of successful enterprises at home and abroad, Wang Dazhou et al. (2001), observed that the institutional arrangement provides preconditions for technological innovation and supporting conditions for institutional innovation thereby, contributing to the growth of the enterprises[13]. Duan Yunlong (2009) concluded that the institutional category that influences technological innovation includes not only the macro institutional environment, but also the meso institutional arrangements between the enterprises and the micro institutional arrangements within the enterprise[14]. For example, the R&D incentive system established within the enterprise belongs to the micro institutional arrangement. According to the characteristics of the enterprises' technological innovation ability, Fu Jiaji (1998) constructed the index system of enterprises' technological innovation ability in R&D, innovation resource investment, management innovation, marketing, innovation tendency and manufacturing[15].

To sum up, the technological innovation plays a decisive role in economic growth however, the important role of institution in technological innovation and economic growth is rather ignored. The enterprise system innovation provides a guarantee for smooth implementation of technology innovation, system innovation and technological

innovation by investing more in R&D and promotes the growth of the economy. It gradually develops into a complex of various capabilities with technological innovation capability as the core and other innovation capabilities as the auxiliary development measures. Although the environment or the system of enterprises is similar, the innovation capability should be diversified especially, for the listed companies with large gaps in industrial attributes there is significant heterogeneity in the innovation capabilities. Based on the aforesaid research, this paper defines the connotation of the enterprise's innovation capability as follows: In a foreseeable period, the enterprise realizes the integration of the internal and external resources through multi-dimensional innovation activities such as technological innovation, institutional innovation and management innovation, and ultimately improves the enterprise's performance and gets economic benefits.

In the technological and economic globalization environment, a new round of scientific and technological revolution is booming, and innovation is becoming more and more open. The advanced theoretical basis represented by collaborative manufacturing has become the pre paradigm. The realization of the innovation mode of openness, cooperation and sharing has proved to be an important way to effectively improve the efficiency of innovation. Of late, the research trend is to explore how to integrate enterprises, governments, and knowledge exploring institutions (such as universities and research organizations) to establish a long-span innovation organization model based on the perspective of knowledge appreciation and the goal orientation of realizing major scientific and technological innovation. As suggested by Chesbrough et al. (2011), companies should find a way to utilize the distributed pools of knowledge possessed by customers, suppliers, universities, national labs, consortia, consultants and even their own competitors[16]. Chen Jin et al. (2012) established a theoretical framework of collaborative innovation from two dimensions, namely integration dimension and interaction intensity, and proved that the collaborative innovation is mainly manifested in the process of industry-university research cooperation[17].

Rexhepi et al. (2019) explored the initial model of knowledge production - the Triple Helix, representing an innovation system model through the interactions of three ‘helices’ in knowledge production: universities-industry-governments[18]. Xie Ruoqing et al. (2020) evaluated the innovation capability of Chinese industrial listed companies; they introduced the collaborative innovation capability into the evaluation system as a primary index[19]. Zhang Zhi He et al. (2016) established the innovation ability index system of listed companies in Shan Xi Province and concluded that the enterprises should closely link technological innovation ability in formulation of technological strategy, collaborative innovation and R&D activities[20]. Although the above findings noticed the importance of collaborative innovation suffers from the main drawback that these studies do not consider the specific indicators that can fully reflect the process of enterprise industry-university research cooperation into the evaluation system. Therefore, based on the collaborative innovation theory and open innovation model, this paper introduces some indicators which missed in the previous evaluation index system of innovation ability, such as the number of industry-university research cooperation platforms, the number of awards for scientific and technological achievements at the provincial, ministerial level or above, the number of innovative R&D projects invested by raising funds, etc.

2. Construction of Enterprise Innovation Capability Evaluation Model

The main research methods to evaluate the enterprise innovation ability focus on the analytic hierarchy process (AHP) and multistage fuzzy comprehensive evaluation method, grey correlation method, principal component analysis and BP neural network model, data envelopment analysis, factor analysis, etc. Li qun, LingKang (2004) used multilevel fuzzy comprehensive evaluation from the six elements level and constructed enterprise innovation ability evaluation index[21]. Zhao Wenyan and Zeng Yueming (2011) used an analytic hierarchy process (AHP) to decompose the index system layer by layer and constructed an evaluation system of enterprise innovation capability[22]. Wang Mengqiu (2012) used analytic hierarchy process to construct an evaluation index system of innovation capability of innovation-oriented enterprises from four aspects: innovation input, innovation realization, innovation output capacity and innovation environment[23].

The AHP can be used to subdivide the main factors into higher index levels according to the process capability model, and then analyze the assigned weight of indicators at each level, which was more intuitive and convenient in processing. Figure 1 depicts the results of the enterprise innovation capability evaluation model construction. Under the technological innovation ability, there are three secondary indexes: technological innovation investment ability, technological innovation transformation ability and technological innovation marketing ability, which fully reflect that the technological innovation is an economic concept rather than a technological concept as a mechanism of continuous operation. The system innovation ability consists of two secondary indexes – the property right system innovation ability and the incentive system innovation ability. The property rights system is the core of the enterprise system which determines the organization form of enterprise property while the operational mechanism is seen as the key to the institutional innovation in state-owned assets management, and the incentive system improves the mechanism of the success rate of technology innovation. Under the management innovation ability, there are two secondary indexes: the enterprise innovation consciousness intensity and the operation innovation management ability, which reflects the consciousness and the ability of the enterprises to integrate the existing resources.

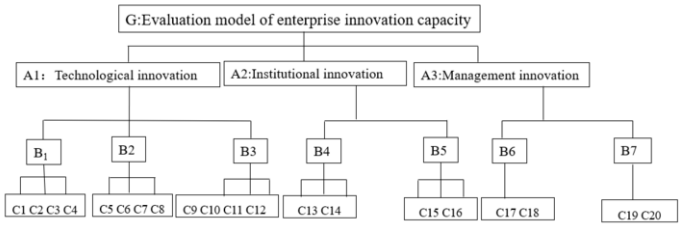

Figure. 1 Evaluation model of enterprise innovation ability

3. An Empirical Study on the Evaluation of Innovation Ability of Listed Companies in Gansu Province

3.1 Construction of innovation capability index system of an enterprise

The evaluation index system of the enterprise innovation capability is divided into three index levels. Under the target level, the innovation capability is decomposed into three basic elements according to the dimension of the enterprise innovation activities, namely, technological innovation capability, institutional innovation capability and management innovation capability, which constitute the first-level index level. There are seven second-level indicators under the first-level indicator layer namely, technological innovation investment ability, technological innovation transformation ability, technological innovation marketing ability, property rights system innovation ability, incentive system innovation ability, enterprise innovation consciousness intensity, and operation innovation management ability. Twenty three-level indicators are set under the second-level indicator layer. Considering the difficulty of data acquisition and the strong willingness of enterprises to publicly disclose information, 20 three-level indicators are finally selected: per capita R&D expenditure, proportion of bachelor degree or above, proportion of R&D expenditure in main business income, proportion of the number of researchers and so on.

Collect index scores at all levels as the core, design the questionnaire, and solicit scoring opinions from six experts engaged in innovative enterprise research in the form of electronic questionnaire, including professors in major universities, general partners of private equity funds with innovative enterprises as investment targets, heads of scientific and innovative financial services companies, etc. Table 1~7 depict the construction of the innovation capability index system of an enterprise used in the study.

Table 1 Enterprise innovation capability index system: Technological innovation investment ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B1 Technological Innovation Investment Ability	C1:Per capita R&D expenditure	Positive index	C1=R&D expenses / total number of active employees
		C2:Proportion of bachelor degree or above	Positive index	C2=Number of employees with bachelor degree or above / total number of on-the-job employees
		C3:Ratio of R&D expense to main business income	Positive index	C3=R&D expenses / main business income
		C4:Ratio of the number of Researchers	Positive index	C4=Number of researchers / total number of active employees

Table 2 Enterprise innovation capability index system: Technological innovation transformation ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B2 Technological Innovation Transformation Ability	C5:Weighted return on equity after deducting non-operating losses	Positive index	C5=(total profit - non operating income + non operating expenditure) * (1 - income tax rate)
		C6:Growth rate of main business income	Positive index	C6=(main business income of the current period / main business income of the previous period) – 1
		C7:Number of awards for scientific and technological achievements at provincial and ministerial level and above	Positive index	C7=Number of scientific and technological achievements of enterprises at provincial and ministerial levels and above
		C8:Per capita patent holdings of Employees	Positive index	C8=Number of valid patents / total number of employees

Table 3 Enterprise innovation capability index system: Technological innovation and marketing ability

First Level	Second Level	Third Level	Attribute	Meaning
A1 Technological Innovation Ability	B3 Technological Innovation and Marketing Ability	C9:Proportion of sales personnel	Positive index	C9=Number of salespeople / total number of active employees
		C10:Per capita sales expense Investment	Positive index	C10=Sales expenses / total number of employees
		C11:Number of investment institutions settled	Positive index	C11=Number of investment institutions among the top ten shareholders
		C12:Number of industry university research cooperation platforms	Positive index	C12=Number of platforms jointly built by enterprises, universities and scientific research institutes

Table 4 Enterprise innovation capability index system: Innovation ability of property right system

First Level	Second Level	Third Level	Attribute	Meaning
A2 Institutional Innovation Ability	B4 Innovation Ability of Property Right System	C13:Shareholding ratio of state-owned legal person	Positive index	C13= State owned shares / total shares
		C14:Proportion of tradable shares	Positive index	C14=Number of outstanding shares / total shares

Table 5 Enterprise innovation capability index system: Incentive system innovation ability

First Level	Second Level	Third Level	Attribute	Meaning
A2 Institutional Innovation Ability	B5 Incentive System Innovation Ability	C15: Proportion of total issued incentives to total share capital	Positive index	C15= Total number of shares / total share capital corresponding to equity incentive plan
		C16: Total annual salary of directors and supervisors	Positive index	C16= Total annual salary of directors, supervisors and other senior managers

Table 6 Enterprise innovation capability index system: Enterprise innovation consciousness intensity

First Level	Second Level	Third Level	Attribute	Meaning
A3 Management Innovation Ability	B6 Enterprise Innovation Consciousness Intensity	C17:Number of innovative R&D projects invested by raising funds	Positive index	C17=The number of projects that raise funds to invest in innovative research and development
		C18:Patent efficiency	Positive index	C18=1-Number of invalid patents/ total number of patents

Table 7 Enterprise innovation capability index system: Operation innovation management capability

First Level	Second Level	Third Level	Attribute	Meaning
A3 Management Innovation Ability	B7 Operation Innovation management capability	C19:Inventory turnover	Positive index	C19=Operating income/average inventory balance
		C20:Management expenditure Efficiency	Positive index	C20=Main business income / management expenses

3.2 Decision making process of analytic hierarchy process

Analytic hierarchy process (AHP)is a systematic analysis method of multi-criteria decision-making proposed by T.L. satty[24], an American operations research scientist and professor at the University of Pittsburgh in the early 1970s. Using AHP method, it is easy to divide many factors into levels according to the process capability model and evaluate and analyze them layer by layer, which is intuitive and simple. However, as the research conclusion summarized by Xu Liping(2015), subjective factors have a great impact on the evaluation of objectives[25].This paper adopts the three scale matrix method (Luo & Wang, 1993;Sang & Lin & Ji,2002; Cao & Wang, 2018) which educes the designer's subjective judgment in the decision-making process [26-28].

3.2.1 Establish hierarchical structure model

The hierarchical structure of some elements is divided into a group of elements dominated by the hierarchical structure, such as the hierarchical structure of some elements. At the same time, these elements are divided into a group of elements dominated by the hierarchical structure according to the hierarchical structure of the elements. For example, the hierarchical structure of these elements is shown in the Figure 2.

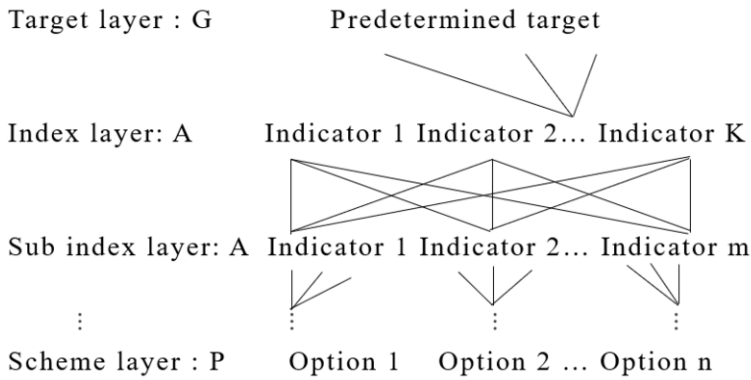

Figure. 2 Structure of ladder level

3.2.2 Comparison and judgment matrix

The judgment matrix is the information basis of AHP method. The value of the judgment matrix element reflects the relative importance of each element in the problem. The traditional judgment and evaluation method adopts the scale of 1 ~ 9, and the meaning of the scale is shown in Table 8.

Table 8 Relative importance judge demarcate of AHP

Scale	Define
1	The two indicators are of equal importance
3	The former is slightly more important than the latter
5	Compared with the two indicators, the former is obviously more important than the latter
7	The former is strongly more important than the latter
9	Compared with the two indicators, the former is more important than the latter
2，4，6，8	The intermediate value of the two adjacent judgments above
The bottom	If the comparison of index I with j makes judgment aij, then the comparison of index j with I makes judgment aji=1/aij

The key link in determining the index weight by AHP method is to establish the judgment matrix at all levels. However, in practical application, it may be difficult for experts to adapt to and be familiar with the 1 ~ 9 scale method when giving the judgment matrix. There is a simplified method. The center of simplification is how to make experts give the judgment matrix more easilyand intuitively. The simplified contents are as follows.

(1) Establish comparison matrix A

A three scale method was used to compare the importance and establish the comparison judgment matrix A_{ij}

Table 9 Value setting

Value setting of a_{ij}	Meaning
0	Indicates that the i-th element is "unimportant" compared with the j-th element
1	Indicates that the i-th element is "equally important" compared with the j-th element
2	Indicates that the i-th element is "important" compared with the j-th element

(2)Then calculate the sum of the row elements of the three scale comparison matrix:

$$r_i = \sum_{j=1}^{n} d_{ij}; i = 1,2,3,...,n$$

Find out the maximum value $r_{\max}$ and the minimum value $r_{\min}$ min from r_i, then compare the two elements corresponding to $r_{\max}$ and $r_{\min}$, and give the so-called base point comparison scale b_m; finally, the direct comparison matrix is transformed into an indirect judgment matrix through the following transformation formula:

$$a_{ij} = \begin{cases} \dfrac{r_i - r_j}{r_{\max} - r_{\min}}(B_m - 1) + 1, r_i \geqslant r_j \\ 1 / \left[\dfrac{r_j - r_i}{r_{\max} - r_{\min}}(B_m - 1) + 1 \right], r_i < r_j \end{cases}$$

This judgment matrix has the following properties:

$$① \begin{cases} 1 / b_m \leqslant a_{ij} \leqslant 1; & a_{ij} < 1 \\ 1 \leqslant aij \leqslant b_m; & aij \geqslant 1 \end{cases}$$

Tthe numerical range of a_{ij} is the scale of $1 \sim b_m$.

② $a_{ij} = 1 / a_{ji}$

The reciprocal property of the symmetric elements of the matrix is still maintained.

③ When $b_m = 9$, it is the scale of 1 ~ 9.

3.2.3 Calculate the relative weight of elements under a single index

This step is to solve the problem of calculating the ranking weight of n elements $A_1, A_2, ..., A_n$ under the index C_k, and carry out the consistency test.

For $A_1, A_2, ..., A_n$, the judgment matrix A is obtained by pairwise comparison, and the eigenvalue of the solution matrix $AW = \lambda_{\max} W$, the obtained W is normalized as the ranking weight of elements $A_1, A_2, ..., A_n$ under the index c_k ,this method is

called the eigenvalue method of ranking weight vector calculation. $\lambda_{\max}$ exists and is unique, W can be composed of positive components. W is unique except for a constant multiple.To check the consistency of the judgment matrix, the consistency index shall be calculated according to formula: $H=(\lambda_{\max}-n)/(n-1)$, $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix.

When $H=0,\lambda_{\max}=n$, the symmetric matrix has complete consistency; When $H>0$, the value of H is often compared with the average random consistency index L. when the random consistency ratio $M=H/L<0.10$, it is considered that the matrix has satisfactory consistency; Otherwise, the matrix needs to be adjusted until it is satisfactory.

For matrices of order 1 ~ 9, the L value is shown in Table 10.

Table 10 The average random coherence weight L

Order number	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

3.2.4 Calculate the combination weight of each layer element

The importance weights of all factors in the previous level can be calculated from the results of the single ranking of the previous level, that is, the total ranking of the levels.

Suppose that the combined weight vector of the elements of layer $k-1$ relative to the total target is α^{k-1}, $\alpha^{k-1}=(\alpha_1^{k-1}\alpha_2^{k-1}...\alpha_m^{k-1})^T$ .The k th layer takes the j th element of the $k-1$ layer as the criterion, and the ordering weight vector of the elements is B_j^k, $B_j^k=\left(b_1^k{}_j b_2^k{}_j ... b_n^k{}_j\right)^T$,the combined weight vector of the elements of layer k relative to the total target is given by the following formula:

$$\alpha^k = B^k \alpha^{k-1}$$

If the calculation results of layer k-1 are known as H_{k-1}, L_{k-1} and M_{k-1}, the corresponding indexes of layer k:

$$H_k=\left(H_k^1 H_k^2 ... H_k^m\right)\alpha^{k-1}$$

$$L_K=\left(L_k^1 L_k^2 ... L_k^m\right)\alpha^{k-1}$$

$$M_k=\left(M_{k-1}+H_k/L_k\right)$$

H_k^i and L_k^i are the consistency index and average random consistency index of the judgment matrix under the i th index of k layer, respectively. When $M_k<0.10$, it is considered that the hierarchical level has satisfactory consistency on the whole k level.

Taking the judgment matrix constructed by A_2 as an example, its 1-9 scale matrix and three scale comparison matrix are respectively expressed as follows:

$$A_{ij} = \begin{pmatrix} 1 & 3 & 5 & 3 \\ 1/3 & 1 & 5 & 3 \\ 1/5 & 1/5 & 1 & 5 \\ 1/3 & 1/3 & 1/5 & 1 \end{pmatrix}$$

$$i = 5,6,7,8,\ j = 5,6,7,8$$

$\lambda_{\max} = 4.7653$, $K = 0.2551, M = 0.2834 > 0.1$ indicates poor consistency

$$B_{\mathrm{ij}} = \begin{pmatrix} 1 & 2 & 2 & 2 \\ 0 & 1 & 2 & 2 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 7 \\ 5 \\ 3 \\ 1 \end{pmatrix} = r_i;$$

$$i = 5,6,7,8,\ j = 5,6,7,8$$

$$r_{\max} = 7, r_{\min} = 1, b_m = 9$$

Indirect judgment matrix:

$$C_{ij} = \begin{pmatrix} 1 & 11/3 & 19/3 & 9 \\ 3/11 & 1 & 11/3 & 19/3 \\ 3/19 & 3/11 & 1 & 11/3 \\ 1/9 & 3/19 & 3/11 & 1 \end{pmatrix} = \begin{pmatrix} 0.5447 \\ 0.0956 \\ 0.1799 \\ 0.1799 \end{pmatrix}$$

$$i = 5,6,7,8,\ j = 5,6,7,8$$

$\lambda_{\max} = 4.1861, K = 0.0620, M = 0.0689 < 0.10$,meets consistency requirements.

Its weight coefficient vector can be expressed as $(0.5477, 0.0956, 0.1799, 0.1799)^T$ .Similarly, the factor indicators of the second and third levels can be calculated.

Based on the comparison matrix given by expert, establish judgment matrix, anti-symmetric transfer matrix, optimal transfer matrix and quasi optimal consistency matrix respectively. The specific assignment results are shown in Figure 3.

3.3 The Result and Analysis of Index Weighting Based on Improved AHP Method

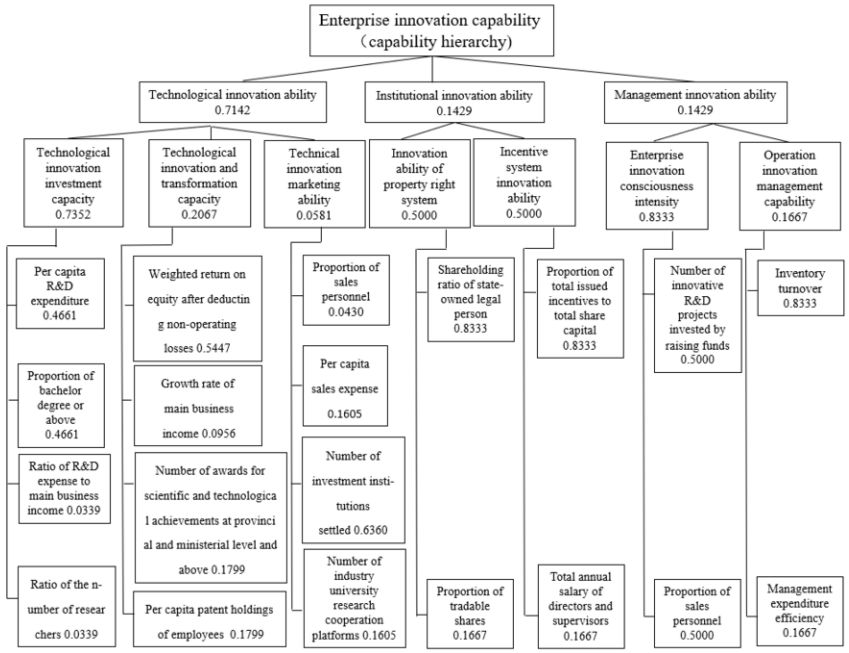

Figure. 3 Index weight based on improved AHP method

Figure 3 shows the weighting results of the enterprise innovation capability evaluation indicators. Among the three primary indicators, technological innovation capability (0.7142) is higher than the institutional innovation capability (0.1429) and the management innovation capability (0.1429), indicating that improving the enterprise's technological innovation capability is still an important path to support enterprises to realize innovation strategy.

The assignment weight of operation innovation management ability (0.1667) reflects the operation of economic resources and inventory management level of the enterprises after investing management expenses, the enterprise innovation consciousness intensity (0.8333) reflects the sustainability of the development of enterprise innovation power and the penetration intensity of enterprise innovation culture. Inventory turnover rate (0.8333) is a direct response to the level of inventory management. Inventory management ability can be said to be the third source of profits of enterprises. Poor inventory management will not only aggravate the overcapacity of manufacturing industries in Gansu Province, but also directly affect their profits. The number of innovative R&D projects raised (0.5000) reflects the importance of innovative and forward-looking thinking of the enterprises. The enterprises use the raised funds for special investment in innovative R&D projects, so as to give full play to the capital link between the enterprises and strategic investors, so as to strengthen the coordination in R&D, capital, business and other related fields.

The property right system innovation ability (0.5000) and the incentive system innovation ability (0.5000) are the core kinetic energy to optimize the internal and external relations of enterprises and coordinate the allocation of factors. The innovation

ability of incentive system (0.5000) reflects the importance of incentive system for the cultivation of innovative talents and teams of the listed companies. Compared with the annual salary incentive, equity incentive can better reflect the advantages of long-term incentive mechanism. Therefore, the assignment weight of the proportion of the total issued incentive to the total share capital (0.8333) is significantly higher than that of the total annual salary of directors and supervisors (0.1667); The shareholding ratio of the state-owned legal persons (0.8333) and the proportion of circulating shares (0.1667) measure the innovation ability of the property right system from two perspectives: property right structure and equity liquidity.

4. Evaluation of Enterprise Innovation Ability - A Case Study of 30 Listed Companies in Gansu Province

Manufacturing has been the most active field of technological innovation for a long time. Seizing the commanding heights and core technologies of manufacturing global value chain has become the only way to realize national rise and regional economic take-off. As the most dynamic micro-subject in regional economic development, listed companies have become the backbone of economic growth.

Based on this, it is planned to explore from the following aspects: Firstly, taking 30 listed companies in Gansu Province from 2016 to 2020 as the research object, the overall innovation ability of the research is carried out, and the innovation ability level of listed companies is comprehensively analyzed; Secondly, combined with the industry attributes, industry characteristics and disclosure of relevant information of listed companies in Gansu Province, the innovation ability is quantified to provide appropriate innovation ability development path for listed companies in Gansu Province.

4.1 Gansu Listed Company Basic Situation Overview

4.1.1 Industry distribution

By October 2021, excluding ST, *ST status and delisted companies, Gansu province has a total of 30 listed companies, including Qilian Mountain, Shouhang High-tech, Asia-pacific Industry, 20 listed companies are affiliated to the manufacturing industry, accounting for 66.67% of the total number of listed companies in Gansu Province. The remaining 10 listed companies are distributed in six industries, including electricity, professional and technical services, wholesale and retail, mining and culture media. In 2020, 10 listed companies in Gansu province are listed on the list of high-tech enterprises recognized by the Department of Science and Technology of Gansu Province, accounting for only 33.33% of the number of listed companies in the province, among which high-tech manufacturing enterprises account 23.33% of the total number of listed companies and 14% of the total number of manufacturing enterprises in the province.

4.1.2 Distribution of registration places

"What kind of better city innovation?" is always the prime focal point of the political attention as regards technology and urban development. Wang Yangjie, MaYingLin (2020) empirically analyzed the relationship between the city administrative level and the enterprise innovation theory hypothesis by using China's industrial enterprise survey data and statistical data[29]. The research shows that the innovation performance of enterprises is highly correlated with the administrative level of the city where they are located, and the enterprises located in the core development region can make better use of the high-quality resources within the region to achieve high-speed innovation development. A total of 19 listed companies in Gansu province are registered in Lanzhou, the provincial capital, while the remaining 11 listed companies are registered in six prefecture-level cities namely, Jiuquan, Tianshui, Baiyin, Longnan, Jiayuguan and Wuwei. Gansu province is an underdeveloped region in the west, and some prefecture-level cities and autonomous regions are facing serious low-level development than Lanzhou, and their economic development modes are restricted to varying degrees.

At present, the business activities of the listed companies in the province are mainly concentrated in Lanzhou and Belarus, and the innovation leading role of "Lanbai Self-created Zone" and "Lanbai Experimental Zone" is further highlighted thus, exacerbating the regional development gap in the province. In the face of unbalanced urban economic development, in order to break the long-term development deadlock, the management of listed companies should put innovation at the core of the overall development, and all industries should break through the bottleneck of various resources through technological docking and communication between enterprises, so as to achieve high-quality innovative development of enterprises. At the same time, in order to slow down the regional development trend of "low in the east and weak in the south", Gansu province should promote the regional innovation development of Jiuquan, Tianshui, Jinchang and Zhangye and further highlight the innovation advantage of Hexi region on the basis of maintaining the "medium strong and high in the west" during the "14th Five-year Plan". Through continuous construction of innovative cities, more cities and states in the province are approaching the goal of realizing the construction of innovative cities, and ultimately provide a better survival and develop environment for enterprise innovation.

4.1.3 R&D inputs and outputs

The number of patents of the listed companies directly indicates the strength of the individual company's innovation ability, which to a larger extent reflects in the output of innovation research results. According to the data retrieved by the China Patent Information Center of the State Intellectual Property Office, there is a wide gap in the independent innovation ability of the listed companies in Gansu Province. The listed company with the largest number of patents is JISCO Hongxing, which owns 1593 patents, accounting for 26.93% of the total number of patents owned by the listed companies in Gansu Province. While the wholesale and retail industry namely, Lanzhou Minbai and Guofang Department neither invested in R&D nor hired any technical R&D personnel.

4.2 Evaluation of Innovation Ability of Listed Companies in Gansu Province

Innovation ability evaluation index system of the listed companies in Gansu province is formed by positive analysis indicators. In order to ensure the index and have good comparison between the maximum eliminate index units and dimensional difference influence on research, this article on the basis of the original data compiled up a cumulative frequency distribution of three indicators, let the cumulative frequency r_{ij} of the third level index of item j of the i th listed company.

Calculate the score of the i th listed company under the evaluation index system of innovation ability of Listed Companies in Gansu Province by using the following equation.

$$S_i = 100 \times \sum_{j=1}^{n} W_j \times r_{i,j}$$

4.2.1 Measurement results of innovation capability

Table 11 reveals the evaluation score and the ranking of different innovation abilities of all the 30 listed companies in the study.

Table 11 Evaluation score and ranking of innovation ability of Listed Companies in Gansu Province

Name	Technological innovation ability		Institutional innovation ability		Management innovation ability		Composite scores	Ranking
	Score	Ranking	Score	Ranking	Score	Ranking		
LKGXco,ltd	81.12	1	80.84	1	78.57	3	80.43682	1
HMKJco,ltd	81.07	2	56.27	23	76.93	4	73.06397	2
HTKJco,ltd	75.30	3	66.99	11	59.37	17	68.60024	3
ZHTBco,ltd	74.37	4	61.37	17	69.34	8	68.41286	4
LSRFco,ltd	74.12	5	61.33	18	52.37	24	65.89563	5
SHGKco,ltd	72.11	6	60.51	19	72.66	5	65.68339	6
ZYMCco,ltd	66.48	7	45.52	29	85.97	2	64.96502	7
DYJSco,ltd	66.04	8	61.39	16	69.76	6	64.74459	8
FCZYco,ltd	65.28	9	70.25	8	50.63	25	63.78027	9
YTSYco,ltd	65.25	10	47.14	28	61.06	15	63.49804	10
DZCMco,ltd	64.24	11	59.64	20	64.06	13	62.32742	11
DHZYco,ltd	63.06	12	61.53	15	65.74	12	61.03982	12
FDTSco,ltd	59.85	13	63.18	14	60.84	16	61.02761	13
QLSco,ltd	58.42	14	75.72	3	68.19	9	60.74933	14
LSZZco,ltd	58.08	15	68.46	9	59.10	19	60.22783	15
SFSNco,ltd	56.56	16	70.42	7	66.01	11	60.12376	16
GSDTco,ltd	55.92	17	66.89	12	69.47	7	58.96015	17
CCDGco,ltd	51.12	18	55.39	24	49.23	27	58.6514	18
JHJco,ltd	49.07	19	66.79	13	49.90	26	57.87399	19
ZXJYco,ltd	48.22	20	75.36	4	61.20	14	55.99208	20
MGGFco,ltd	44.88	21	57.02	21	87.25	1	54.19665	21
JGHXco,ltd	44.31	22	75.23	5	53.04	23	53.95715	22
YSJTco,ltd	41.97	23	57.02	22	66.25	10	51.88404	23
JYMDco,ltd	41.85	24	76.51	2	56.62	21	51.75505	24
GZXco,ltd	41.73	25	50.72	26	37.29	30	51.05716	25
BYYSco,ltd	39.12	26	68.28	10	37.99	29	49.86853	26
LSGCco,ltd	37.66	27	74.37	6	59.27	18	49.37064	27
GFJTco,ltd	36.14	28	53.75	25	54.34	22	46.17898	28
HTJYco,ltd	34.72	29	45.25	30	58.96	20	45.57054	29
LZHHco,ltd	29.69	30	49.97	27	40.31	28	44.96227	30

4.2.2 Analysis of innovation capability

(1) Technological innovation ability: Listed companies in the brewing manufacturing industry and wholesale and retail industry represented by Lanzhou Huanghe River, Huangtai liquor industry, Guofang Department and Lishang Guochao rank the lowest due to the problems of insufficient investment in innovation, R&D and low efficiency in achievement transformation. The specific manifestations are: zero investment in enterprise R&D funds, no registered patents and low proportion of R&D technicians. Mining enterprises (mining auxiliary) and manufacturing enterprises (special equipment and medicine) namely, Heimer technology, Lanke High Tech and Longshenrongfa rank high in the technological innovation ability due to continuous investment in scientific and technological innovation thereby shifting to high-tech manufacturing enterprises. In 2020, there were only 9 listed companies recognized as high-tech enterprises by Gansu Provincial Department of Science and Technology, of which the belongs to the field of cultural media and the rest 8 are manufacturing enterprises.

(2) Institutional innovation ability: On the basis of the large weight assigned to the innovation ability of the incentive system, Lanke High Tech and Jingyuan Coal Power rank first and second in terms of absolute advantages in the total annual salary of the directors and supervisors and the proportion of the total issued incentives to the total share capital. Among the listed companies only seven firms implement the equity incentive plan and Lishang Guochao ranks first with 2.87% of the total incentive, which reflects that these enterprises use the positive incentive policy to inspire its employees so as to ensure the stability of the talent team and the gradient construction of talent reserve. In terms of the innovation ability of property right system, compared with the manufacturing enterprises with 100% circulating shares such as Lanke Hi-Tech and Shangfeng cement, the proportion of Gan consulting circulating shares is only 46.95%, which restricts the development of the enterprise due to the weak circulation of shares. A total of 18 enterprises are held by state-owned legal entities. The diversification of investors can stimulate the innovation vitality and passion of enterprises on the basis of relatively dispersed equity.

(3) Management innovation ability: Taking the first ranked Mogao shares as an example, in recent years, it has not only increased the investment in management expenses, but also invested the raised funds in innovative R&D projects, which has significantly improved the efficiency of patents. In com\parison to the other three listed companies in the brewing manufacturing industry, it has shown a strong sense of innovation and a high level of operation and management ability. Listed manufacturing companies represented by Lanke Hi Tech and Manor ranch also performed well in management innovation. With the adjustment of the global industrial chain, traditional manufacturing enterprises alleviate overcapacity by improving inventory management level, and finally improve the profitability and broaden financing channels.

5. Validity Test of Index System

The evaluation criteria of the rationality of the index system include the independence, redundancy and universality of the index system. Referring to the ideas of Fu Yun and Liu Yijun (2009), the redundancy degree is used to measure the independence and redundancy of the index system while, the sensitivity degree is used

to measure whether the index system has reliable spatial universality[30].

5.1 Index System Redundancy Test

The redundancy of the index system is used to measure the independence of the index system and the redundancy of the index. Set the correlation coefficient matrix of the index system X^p as R^p $(p=1,2,...,n)$, where p represents the p th index system.

$$R = \begin{bmatrix} 1, & r_{12}, r_{13}, \ldots, r_{1n} \\ r_{21}, & 1, r_{23}, \ldots, r_{2n} \\ \cdots & \cdots & \cdots \\ r_{n1}, & 1, r_{n3}, \ldots, r_{nn} \end{bmatrix}$$

The redundancy calculation formula of RD is given by:

$$RD = \frac{\sum_{i=1}^{n_p}\sum_{j=1}^{n_p}\left|r_{ij}\right| - n_p}{{n_p}^2 - n_p}$$

The RD critical value is set to 0.5. It is generally believed that when RD is less than or equal to 0.5, the indicator system passes the redundancy test; otherwise, the indicator system needs to be modified. SPSS25.0 was used to test the correlation of indicators, and the sum of the absolute correlation coefficient of each indicator was calculated to be 93, RD=0.192 < 0.5, and the redundancy did not exceed the critical value, so there was no need to adjust the indicator. Meanwhile, the simplification and independence of the indicator system were demonstrated.

5.2 Sensitivity Test of Index System

Enterprise innovation ability evaluation result is the ability of evaluation objects, evaluation standard, evaluation model and index weight under the joint action of multiple factors. In index system of sensitivity analysis there is an error in the process of inspection evaluation method because the evaluation result is influenced by the kind of method used to measure the universality of the index system in evaluation of different types of objects. For a set of evaluation index system, the sensitivity of evaluation result X_i is defined as:

$$SD_i = \frac{\triangle V(Xi)/V}{\triangle Xi/Xi}$$

Sensitivity of index system is represented as:

$$SD = \frac{1}{n_p}\sum_{i=1}^{n_p} SD_i$$

The physical meaning of index system sensitivity is very clear, indicating the relative change of evaluation results caused by each change of unit relative amount of single or multiple indexes in the index system. From the perspective of the evaluation of index system rationality, the larger the $|SD|$ more is the sensitive index system, and the worse is its universality. A 1% change in the index value of the index system allows

a system error of no more than 5%, so the $|SD|$ should not exceed 5. When $SD = 0.976$, the absolute value is far less than 5, indicating that the index system has strong universality. On the other hand, when comprehensive $RD = 0.192$, it is considered that the evaluation index system of enterprise innovation capability has passed the sensitivity test and has strong universality and high reliability.

6. Conclusion and Enlightenment

On the basis of scientific, operable and comparable, this paper combs and summarizes the existing literature, demonstrates that the innovation ability of listed companies is a comprehensive ability, constructs the enterprise innovation ability evaluation index system and enterprise innovation ability evaluation model from the three levels of technological innovation ability, institutional innovation ability and management innovation ability, and uses the improved analytic hierarchy process to determine the weight of indicators at all levels, It provides a scientific measurement standard for enterprises to evaluate their own innovation ability, provides an evaluation basis for provinces, cities (prefectures) to identify the scientific and innovative attributes of enterprises, and provides a reference for investors to make reasonable investment decisions. At the same time, limited by the length, there are few literatures to test the effectiveness of the innovation capability evaluation index system after completing the construction. This paper uses the rst evaluation method to verify the operability and applicability of the enterprise innovation capability evaluation index system.

In view of the upcoming research, the author believes that some descriptive indicators can appropriately be introduced into the index system, and a five-level quantitative table is envisaged to be used to score them, so as to eliminate the adverse impact of the unavailability of the index data on the accuracy of the evaluation results to a greater extent. Meanwhile, the relevant departments should strengthen the implementation of the new securities law, revise the management measures for information disclosure of listed companies, and form an information disclosure rule system guided by the needs of investors, It helps to build a more detailed index system.

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