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Evaluation of Innovation Efficiency of Listed Baijiu Enterprises Based on Three-stage DEA Model

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ABSTRACT

Baijiu industry, as a pillar industry of hundreds of billions of dollars, is an important part of the national economy, and has been strongly supported by the national and local governments at all levels. However, as China's consumption upgrading speeds up, the process of the liquor industry is accelerating, and the market competition led by homogenised products is intensifying, liquor enterprises need to seek an innovation path suitable for their own enterprises in order to form a sustainable competitive advantage. Using a three-stage DEA model, this paper measures the innovation efficiency of 18 listed liquor enterprises in 2022, and analyses the relationship between environmental variables and the innovation efficiency of listed liquor enterprises. The results show that environmental factors such as government subsidies, GDP per capita, and equity concentration all have a significant impact on the slack variables of the firms' R&D expenditure investment and the slack variables of R&D personnel investment. From a general point of view, the innovation efficiency of China's listed liquor enterprises still needs to be improved, and the gap between enterprises is large.

KEYWORDS

Baijiu Listed Companies; Innovation efficiency; Three-stage DEA model

1. INTRODUCTION

With the rapid development of China's economy and the continuous improvement of the living standards of the population, the liquor industry has also been highly valued and rapid development. Although the liquor industry was hit by the epidemic before, it still showed strong resilience and market potential. According to data from the National Bureau of Statistics, in 2022, there were 963 domestic liquor enterprises above designated size, completing sales revenue of 662.65 billion yuan, an increase of 9.6% compared with the same period in 2021, and realizing a profit of 220.17 billion yuan, a year-on-year increase of 29.4%, which is enough to show that the liquor industry has played a very important role in China's economic development. With its deep cultural heritage and extensive market demand, the liquor industry not only contributes a large amount of fiscal revenue for the state and localities, but also effectively drives the integrated development of one, two, three industries, solves a large number of social employment, and promotes the revitalization of the countryside. In addition, for Guizhou, Sichuan, Shanxi and other liquor provinces and Renhuai, Suqian, Yibin, Luzhou and other liquor capital, liquor industry as a local pillar-type industry, for the provincial and municipal economic development has made great contributions. Of course, the liquor industry in the rapid development of the same time, but also faced with many challenges, such as consumption upgrade driven by the intensification of competition in the market, the market concentration increases at the same time so that enterprises are facing the elimination of advantages and disadvantages, as well as a new generation of consumers to the rise of the market changes, and so on. Whether it is for quality capacity expansion or to comply with the trend of liquor consumption diversification, liquor industry can not be separated from innovation. Based on this, it is necessary to carry out a scientific evaluation of the innovation efficiency of liquor enterprises, analyze the important factors affecting the enhancement of the innovation efficiency of liquor enterprises, so as to put forward measures to improve and optimize the proposal, and help liquor enterprises to improve production efficiency, promote industrial upgrading, and achieve high-quality development.

2. LITERATURE REVIEW

There has been a lot of literature, which has laid a good foundation for the research related to the innovation efficiency of enterprises. According to economic theory, innovation efficiency refers to the efficiency of transformation between inputs of production factors and outputs of research and development (R&D). Existing studies have generally used two methods to measure innovation efficiency, one is Data Envelopment Analysis (DEA), and the other is Stochastic Frontier Model (SFA). Data Envelopment Analysis (DEA) was proposed by Charnes et al [1] in 1978 to assess the efficiency of the public and non-profit sectors, and since then DEA models have been used to measure efficiency in different industries. Ling (2013) used the DEA model to measure the production efficiency of listed liquor companies in China from 2008 to 2011, and combined with the DEA improvement value, proposed corresponding measures for the improvement of enterprise production efficiency [2]. Chu et al. (2013) compared the financing efficiency of property and casualty insurance companies from 2007 to 2011 using the DEA model, and found that the financing scale efficiency of property and casualty insurance companies is slightly higher than the pure technical efficiency [3]. Wang (2022) used the DEA method to measure the technological innovation efficiency value of new energy automobile listed companies, and found that the overall technological innovation efficiency of new energy automobile companies is low, mainly due to the low pure technology efficiency [4]. The stochastic frontier analysis (SFA) method needs to establish the production function first, then solve the problems caused by stochastic factors and analyze the influencing factors. Chen (2008) used the SFA model to measure and analyze the efficiency of R&D in 31 provinces and cities in China, and found that the efficiency of R&D and the level of economic development are not necessarily in a positive relationship [5]. Li et al. (2023) used the SFA model to conduct an empirical study on the investment efficiency of listed companies in China's textile industry and its influencing factors, and found that the existence of executive equity incentives and the improvement of profitability negatively affects technological inefficiency [6].

The research object is mainly divided into macro level, meso level and micro level.The macro level mainly studies the innovation efficiency of different regions and cities. Ni and Lin (2021) used the SE-DEA model to measure the science and technology innovation efficiency of 21 cities and municipalities in Guangdong Province in 2018, and discussed them separately after ranking them [7]. Wang et al. (2022) measured the S&T innovation efficiency of high-tech industries in the Yangtze River Delta (YRD) region from 2007 to 2020 based on a three-stage DEA model with shared inputs, and found that its overall efficiency showed a steady upward trend, while there was an imbalance in the development of the S&T innovation level of three provinces and one city in the YRD region [8]. The meso level mainly studies the innovation efficiency of different industries or sectors. Xu et al. (2020) measured the innovation efficiency of the animation industry in 25 provinces in China from 2011 to 2016, and found that this innovation efficiency presents a stepwise situation consistent with the regional economic development, all of which are in a slowly declining trend [9]. Lu and Meng (2022) measured the technological innovation efficiency of the strategic emerging industries in general and the seven major subsectors, and found that the overall technological innovation efficiency of the industry is low, and there are obvious differences in the innovation efficiency between different subsectors [10]. The micro level mainly studies the innovation efficiency of different types of enterprises and universities and other objects. Song and Zhang (2022) empirically analyze the regional heterogeneity and dynamic change of technological innovation efficiency of China's high-tech industries by using the DEA-Malmquist model, and find that there are large differences in the regional innovation efficiency of China's high-tech industries, and that both the growth of scale efficiency and technological progress are the key factors driving the growth of innovation efficiency of the high-tech industries [11]. Ye et al. (2023) used the DEA model to measure the scientific research efficiency of 32 “double first-class” universities, and the comprehensive efficiency of scientific research and innovation of Chinese universities has continued to grow steadily, in addition to the geographical and hierarchical differences in efficiency were also explored [12]. The research perspective has also changed from a single efficiency measurement to a combination of efficiency measurement and influencing factors. For example, Zhou et al. (2013) used a three-stage DEA model to measure China's regional innovation efficiency from 1998 to 2010, and found that environmental factors such as government support, financial support, and foreign direct investment all have an impact on innovation efficiency, and that the innovation efficiency of each region is more consistent with the objective facts after excluding the influence of environmental factors [13]. Wang and Sui (2022) used a three-stage DEA to measure the innovation efficiency of 30 provincial-level administrative regions in China, and found that the synergistic agglomeration of productive service industries and high-tech industries had a significant positive impact on regional innovation efficiency [14]. Based on the perspective of digital transformation, He et al(2023). evaluated the innovation efficiency of manufacturing enterprises and analyzed the influencing factors by using the three-stage DEA model and the Tobit regression model, and found that the overall innovation efficiency of enterprises was at a low level, and the digital economy, governmental support, and industry competition were the external environmental factors affecting the innovation efficiency of enterprises, whereas the enterprise size, age of the enterprise, and equity concentration factors are important factors affecting the adjusted enterprise innovation efficiency [15].

At present, the domestic research on liquor enterprises using the DEA model mainly includes liquor production efficiency, liquor operating efficiency and other aspects, while the research on liquor innovation efficiency is less. Based on this, this paper adopts a three-stage DEA model, focusing on measuring the innovation efficiency of China's liquor listed enterprises, taking into account the environmental factors affecting innovation efficiency, exploring the differences in the level of innovation efficiency of liquor listed enterprises, and providing references for the optimisation of the allocation of innovation resources for liquor enterprises, the grasp of the direction of innovation development and the implementation of government innovation policies.

3. RESEARCH METHODS AND INDEX SYSTEM CONSTRUCTION

3.1. Research Methods

Data Envelopment Analysis (DEA), is a research method used to evaluate the relative efficiency of multi-indicator inputs and outputs of decision-making units (DMU).The principle of DEA model is to take the optimal inputs and outputs as the production frontier, and use the technique of nonparametric linear programming to construct the data envelopment curve.The DEA model usually contains two kinds of constant scale payoffs and variable scale payoffs, and the results of the measurement are not affected by the data units and weight settings [16]. However, the traditional DEA model cannot exclude the influence of environmental factors and random disturbance terms on the efficiency value, therefore, this paper adopts the three-stage DEA model proposed by Fried et al [17] for calculation, and its specific steps are:

Stage 1: Traditional DEA Model

Depending on the specific research question, DEA models are classified as input-orientated and output-orientated, with input-orientation meaning that input reductions are considered while outputs remain constant, and output-orientation meaning that outputs are increased while inputs remain constant. Due to the uncertainty of corporate innovation, the output outcomes are not easy to be controlled. Therefore, this paper chooses the input-oriented BCC (variable returns to scale) model to measure the innovation efficiency of enterprises. The basic model is set up as follows:

$$\min[\theta - \varepsilon(e_1^T S^- + e_2^T S^+)]$$

$$s.t.\begin{cases} \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} Y_j \lambda_j + S^+ = Y_0 \\ \lambda_j \geq 0, S^- \geq 0, S^+ \geq 0 \end{cases}$$

Where j = 1, 2, ..., n denotes the decision unit, X is the innovation input variable, Y is the innovation output variable, e_1^T and e_2^T are unit vectors,S^- and S^+ are slack variables.

Stage 2: Stochastic Frontier Model (SFA)

Based on the target values of the input variables obtained in the first stage, the slack variables of the input variables were determined and used as the explanatory variables and the environmental variables as the explanatory variables, and the SFA-like model was used to exclude the effect of the environmental factors. The model is set up as follows:

$$S_{ij} = f^j(z_j,\ \beta^j) + v_{ij} + u_{ij}, i = 1,2,\cdots,N; j = 1,2,\cdots,P$$

Where S_{ij} is the slack variable, z_j is the environmental variable, β^j is the coefficient of the environmental variable, $v_{ij} + u_{ij}$ is the mixed error term, v_{ij} denotes random disturbances, u_{ij} denotes managerial inefficiency, where $v_{ij} \sim N(0,\ \sigma_{jv}^2)$, $u_{ij} \sim N^+(\mu^j,\ \sigma_{jv}^2)$. The SFA regression is to remove the environmental factor and the stochastic factors from the efficiency measure in order to adjust all decision units to the same external environment. The adjustment formula is as follows:

$$X_{ni}^A = X_{ni} + \left[\max\left(f(z_i;\ \widehat{\beta_n}) - f(z_i;\ \widehat{\beta_n})\right)\right] + [\max(v_{ni}) - v_{ni}],$$

$$i = 1,2,\cdots,I; j = 1,2,\cdots,N$$

Where X_{ni}^A and X_{ni} denote the adjusted and pre−adjusted innovation inputs, respectively, $\max\left(f(z_i;\ \widehat{\beta_n}) - f(z_i;\ \widehat{\beta_n})\right)$ is the adjustment to the environmental factor, $\max(v_{ni}) - v_{ni}$ denotes the adjustment of all decision units to the same stochastic disturbance condition.

Stage 3: adjusted DEA model

The second-stage adjusted innovation input variables and unadjusted innovation output variables were substituted into the traditional DEA model to measure the innovation efficiency of listed liquor companies after removing environmental factors and random disturbances.

3.2. Index System Construction

This paper draws on existing literature on the selection of innovation efficiency evaluation indicators, from the three first-level indicators ‘input indicators, output indicators, environmental variables’ to build a multilayer indicator system, as shown in Table 1.

Table 1. Evaluation index system of innovation efficiency of listed Baijiu companies

Level 1 indicators	Level 2 indicators	Level 3 indicators	Indicator definitions
Input indicators	Human inputs	R&D Staff Input	Number of R&D staff in listed companies
	Capital inputs	Investment in R&D	Amount of R&D investment by listed companies
Output indicators	Technical outputs	Patent Applications	Number of patent applications filed by listed companies in the year
	Economic output	Main business income	Revenue from principal activities in the annual reports of listed companies
Environmental variables	Government support	Government Subsidies	Total government subsidies to listed companies
	Economic level	GDP per capita	Regional GDP/total population
	Enterprise Scale	Total Assets	Total assets of listed companies at the end of the period
	Enterprise Management	Shareholding Concentration	Shareholding ratio of the largest shareholder
	Enterprise Type	Nature of Shareholding	1 for state-owned enterprises, 0 for private enterprises

(1) Selection of input indicators

R&D investment is a factor input directly related to enterprise innovation activities, mainly including human input and capital input [18]. Enterprise innovation activities can not be carried out without continuous capital investment, this paper chooses the amount of R&D investment as an indicator to measure the level of capital investment. Similarly, enterprise innovation is also inseparable from human resources, R&D personnel is exactly one of the necessary elements of enterprise innovation, so this paper chooses R&D personnel input as an indicator of human input.

(2) Selection of output indicators

The innovation outputs of liquor enterprises mainly include technical outputs and economic outputs. Technological output mainly contains patent, copyright and other forms, of which patent output is the most common and widely used indicator [15]. Considering the influence of the specific preference of the examination organisation and the time lag of examination, this paper chooses the number of patent applications as the technical output indicator [19]. The economic output indicator is an indicator that can reflect the economic benefits and market value brought by the enterprise's innovation activities, and this paper chooses the main business revenue as the economic output indicator.

(3) Environment variable selection

The environmental variables should not only be free from the subjective control of the sample but also have a significant impact on the innovation efficiency of the sample. Therefore, this paper chooses the following five environmental variables: a) government support. Baijiu listed companies often receive financial support from the government, so this paper takes the amount of government subsidies disclosed in the annual reports of listed companies as the measurement variable of government support. b) Economic level. To measure the regional economic level, Tong Chang uses the indicator of regional GDP per capita, which can reflect the local economic development level of investment in the innovation industry. c) Enterprise size. Larger firms tend to have sufficient capital or favourable external financing conditions, and are therefore measured by total enterprise assets. d) Shareholding Concentration. This is used to reflect the distribution of the company's equity, and is generally measured by the proportion of shares held by the largest shareholder. e) Nature of equity.

Firms' innovative behaviour is affected by the nature of their shareholding, so it is measured by the nature of the first largest shareholder.

3.3. Data Sources

The research object of this paper is A-share liquor listed enterprises, excluding ST, *ST and enterprises with serious data missing, and finally selecting 2022 data of 18 liquor listed enterprises as research samples. The data on R&D investment, number of R&D personnel, government subsidies, main business revenue, total assets, equity concentration, and nature of equity are from the annual reports released by listed companies and CSMAR database, the number of corporate patent applications are from CNRDS, the China Research Data Service Platform, and the GDP per capita is from the National Bureau of Statistics. The missing part of data for individual indicators is filled in by linear interpolation.

4. RESULTS AND DISCUSSION

4.1. Empirical Results of Traditional DEA Models

Using DEAP2.1 software, the cross-section data of 18 listed baijiu enterprises in 2022 were substituted into the input-oriented BBC model (with variable returns to scale) to measure the innovation efficiency of baijiu enterprises without excluding the effects of environmental factors and random errors, and the results are shown in Table 2.

Table 2. Evaluation of Innovation Efficiency of Listed Baijiu Enterprises, 2022 (Before Adjustment)

corporations	TE	PTE	SE	Return on scale
Luzhou Laojiao	0.783	1	0.783	drs
Gujinggong Liquor	0.527	1	0.527	drs
Jiugui Liquor	0.838	1	0.838	irs
Wuliangye	0.577	1	0.577	drs
Shunxin Agriculture	0.511	0.651	0.784	irs
Yanghe Brewery	0.273	0.293	0.933	irs
Tianyoude Highland Barley Spirit	0.213	0.574	0.370	irs
Yilite	0.168	0.544	0.308	irs
Golden Seed Winery	1	1	1	-
Kweichow Moutai	1	1	1	-
Laobaigan Liquor	1	1	1	-
Shede Spirits	0.505	0.536	0.943	irs
Swellfun	1	1	1	-
Shanxi Xinghuacun Fen Wine	1	1	1	-
Yingjia Distillery	0.189	0.229	0.828	irs
King's Luck Brewery	0.587	0.612	0.958	irs
Kouzi Distillery	0.313	0.513	0.611	irs
Jinhui Liquor	0.262	0.365	0.716	irs
average value	0.597	0.740	0.787	

(Note: TE is combined efficiency, PTE is pure technical efficiency, SE is scale efficiency; irs is increasing returns to scale, drs is decreasing returns to scale, and - indicates constant returns to scale.)

As a whole, the mean value of comprehensive efficiency of listed liquor enterprises is 0.597, indicating that there is 40.3% resource waste in listed liquor enterprises in 2022, which is a big gap from the efficiency frontier. The mean value of pure technical efficiency is 0.740, indicating that the pure technical efficiency level of listed liquor enterprises is not high. The mean value of scale efficiency is 0.787, indicating that listed liquor enterprises have not yet reached the optimal R&D scale. In addition, scale efficiency is higher than pure technical efficiency, indicating that the overall lower innovation efficiency is more due to pure technical efficiency.

In terms of the comprehensive efficiency of each enterprise, referring to Zhang et al [20] and et al [21] on the way of dividing the innovation ability, this paper considers that the DEA efficiency value is lower than 0.2 indicates a weak innovation ability, [0.2, 0.5) indicates weaker, [0.5, 0.8) indicates general, [0.8, 1) indicates stronger, and equals to 1 indicates strong, which is located in the frontier surface of efficiency. From the table, it can be found that five enterprises, such as Golden Seed Wine, Kweichow Moutai and Laobaigan Liquor, have an integrated efficiency value of 1, which indicates that they are strong in innovation and are located on the frontier of efficiency. In addition to that, the comprehensive efficiency of Jiugui Liquor is 0.838, which is also at a high level. The above six enterprises can integrate the internal and external innovation resources of the enterprise and reasonably optimise the allocation of resources on this basis, so as to keep the innovation efficiency of the enterprise at a relatively high level. On the other hand, Luzhou Laojiao, Gujinggong Liquor, Wuliangye and other 5 enterprises have an average level of innovation, and the remaining 7 enterprises have a lower level, indicating that without taking into account the influence of environmental variables and random errors, the innovation efficiency of most listed liquor enterprises has a large gap with the frontier surface, and their innovation ability is yet to be further improved.

4.2. Empirical Results of the SFA Regression

In this stage, the slack variables of R&D personnel investment and R&D expenditure investment obtained in the first stage are used as the explanatory variables, and government subsidies, GDP per capita, total assets, equity concentration, and the nature of equity are used as the explanatory variables to construct the SFA regression model using frontier4.1, and the empirical results are shown in Table 3.

Table 3. Empirical results of the second phase of SFA simulation

Variable	R&D personnel input slack variable		R&D expenditure input slack variable	
	Coefficient	T-value	Coefficient	T-value
constant value	-1.07E+02	-4.20E+00***	-3.19E+02	-3.77E+01***
Government Subsidies	1.64E+01	4.63E+00***	7.78E+01	1.64E+01***
GDP per capita	1.66E+02	2.45E+01***	4.68E+03	2.35E+02***
Total Assets	-3.93E+01	-4.63E+00***	3.66E+03	1.43E+03***
Shareholding Concentration	1.78E+02	4.63E+01***	-1.32E+03	-4.14E+02***
Nature of Shareholding	-6.85E+01	-3.69E+00***	-3.42E+03	-2.23E+02***
σ^2	2.96E+04	2.96E+04***	3.61E+07	3.61E+07***
γ	0.999999	1.19E+05***	0.999999	7.18E+06***
LR	0.93E+01*		0.14E+02**	

(Note: ***p<0.01, **P<0.05, *p<0.1)

The analysis shows that the LR values of the two regression models have achieved significant at the 10% level, rejecting the original hypothesis that there is no inefficiency term, indicating that the SFA model setting is more reasonable. The γ values of the SFA regression of the slack values of the two variables, R&D personnel input and R&D expenditure input, are close to 1, indicating that the redundancy of the input variables is mainly dominated by the managerial inefficiency term, and the effect of random errors is relatively limited.

By observing the regression coefficients of the relevant variables, it can be seen that: the role of government subsidies for the two slack variables is significantly positive, indicating that at the present stage of China's government subsidies to the liquor industry may be over-invested phenomenon, and the increase in the government's investment has led to a waste of R & D investment instead. GDP per capita also has a significant positive effect on the two slack variables, indicating that economically developed regions can attract more investment and R&D personnel, which is also more likely to cause over-investment in R&D of enterprises. The negative correlation between total enterprise assets and the R&D personnel input slack variable indicates that larger enterprises have excellent R&D teams, and R&D personnel have clear job responsibilities and division of labor; and the positive correlation with the R&D expenditure input slack variable indicates that enterprises may be involved in too many R&D projects, which leads to dispersion of resources. Concentration of equity helps to reduce the waste of R&D expenditures, which indicates that in highly concentrated firms, shareholders will take a more conservative approach to innovation to avoid possible risks, but concentration of equity also leads to redundancy of R&D personnel, which is mainly due to the fact that some firms may have the phenomenon of "insider control", and do not use all of the redundant resources for R&D and innovation. This is mainly due to the fact that some firms may have "insider control" and do not use all of their redundant resources for R&D and innovation activities, but rather keep them for themselves. The nature of shareholding reduces the redundancy of R&D investment. In the sample selected for this paper, there are 12 enterprises, including Kweichow Moutai, Wuliangye, and Shanxi Xinghuacun Fen Wine, which are state-controlled and occupy a large market share, indicating that state-owned enterprises have relatively strong financial strength, and they enjoy more preferential treatment in terms of policies and taxes, which also provide great support and guarantee for the innovation activities of the enterprises.

4.3. Adjusted DEA Model Empirical Results

The second stage of the likelihood SFA regression analysis shows that the presence of environmental factors affects different R&D inputs differently, biasing the estimates of the innovation efficiency of decision-making units in different environments. Therefore, in this stage, the interference of environmental factors is excluded, and the DEA method is used to re-measure the innovation efficiency of listed liquor companies, and the results are shown in Table 4.

Table 4. Evaluation of Innovation Efficiency of Listed Baijiu Companies, 2022 (Adjusted)

corporations	TE	PTE	SE	Return on scale
Luzhou Laojiao	1	1	1	-
Gujinggong Liquor	0.984	1	0.984	drs
Jiugui Liquor	0.286	0.765	0.374	irs
Wuliangye	1	1	1	-
Shunxin Agriculture	0.585	1	0.585	irs
Yanghe Brewery	0.293	0.430	0.681	irs
Tianyoude Highland Barley Spirit	0.256	1	0.256	irs
Yilite	0.105	0.536	0.195	irs
Golden Seed Winery	0.937	1	0.937	irs
Kweichow Moutai	1	1	1	-
Laobaigan Liquor	0.591	0.808	0.731	irs
Shede Spirits	0.731	1	0.731	irs
Swellfun	0.425	1	0.425	irs
Shanxi Xinghuacun Fen Wine	0.708	0.911	0.777	irs
Yingjia Distillery	0.297	0.543	0.547	irs
King's Luck Brewery	0.633	0.946	0.670	irs
Kouzi Distillery	0.131	0.612	0.214	irs
Jinhui Liquor	0.396	0.652	0.607	irs
average value	0.575	0.845	0.651	

On the whole, after eliminating the influence of environmental factors, the average value of the comprehensive efficiency of listed liquor enterprises in the third stage of DEA analysis is 0.575, which is 0.022 lower than the average value of the first stage, indicating that the influence of environmental factors overestimates the innovation efficiency of the enterprise, and the real innovation efficiency is relatively low. In the third stage, the average value of pure technical efficiency of listed liquor enterprises as a whole is 0.845, compared with the average value of efficiency in the first stage increased by 0.105, indicating that the environmental factors have a negative impact on the technology and management level of listed liquor enterprises, and the enterprises should improve the environmental factors that are unfavorable to their own development, and reduce the negative impact of the environmental factors. The mean value of scale efficiency in the third stage is 0.651, which is 0.136 lower than that in the first stage, which also indicates that the influence of environmental factors leads to the overestimation of scale efficiency in the first stage. In addition, scale efficiency is significantly lower than pure technical efficiency, indicating that most of the lower innovation efficiency is due to lower scale efficiency.

From the perspective of the adjusted comprehensive efficiency of each enterprise, there are 10 enterprises such as Luzhou Laojiao, Gujinggong Liquor, Wuliangye, etc., whose comprehensive efficiency values have increased, indicating that the environmental factors have a greater negative impact on these 10 enterprises, and that the innovation efficiency values are more realistic after removing the environmental variables, whereas there are 7 enterprises such as Jiugui Liquor, Yilit, and Golden Seed Winery, etc., whose comprehensive efficiency values have decreased significantly, indicating that these 7 enterprises are affected by the The positive influence of environmental factors is larger, and once the innovation environment changes, the normal development of enterprises will also be affected to some extent. It is worth mentioning that the comprehensive efficiency value of Kweichow Moutai, as the enterprise at the tip of the liquor industry tower, is still 1, which indicates that the innovation efficiency value of this enterprise is still high after eliminating the relevant environmental variables, and that the development ability of its enterprise is strong. In addition, from the viewpoint of scale efficiency, there are 14 enterprises such as Jiugui Liquor, Shede Spirits and

Shanxi Xinghuacun Fen Wine with incremental scale payoffs after adjustment, indicating that there is still a certain gap between the scale of innovation investment and the optimal scale of these enterprises, and that they can appropriately expand their R&D investment. Kweichow Moutai, Wuliangye and Luzhou Laojiao have unchanged returns to scale, indicating that they are at the optimal scale of innovation investment. The diminishing scale reward of Gujinggong Liquor indicates that the current R&D scale of this enterprise has exceeded the optimal level, and it should consider adjusting its R&D investment in the light of the actual situation of the enterprise.

5. CONCLUSIONS AND RECOMMENDATIONS

Taking 18 listed liquor enterprises in 2022 as the research object, this paper measures the innovation efficiency of listed enterprises and analyzes their influencing factors through a three-stage DEA model. The study found that: first, the innovation efficiency of listed liquor enterprises in China is not high at this stage, and the gap between enterprises is large. Second, environmental factors such as government subsidies, GDP per capita, and Shareholding Concentration can significantly affect the R&D investment of enterprises. Third, after removing the effects of environmental variables and random interference terms, the innovation efficiency of most enterprises has improved, but overall, the gap between enterprises is still large. Based on the above conclusions, this paper puts forward the following recommendations:

From the perspective of enterprises, firstly, they should increase innovation investment and research and development, emphasize the transformation of production technology and the upgrading of outdated equipments, and promote the transformation of innovation resources with more advanced technology, as well as reasonably allocate capital and human resources to avoid the inefficiency of innovation caused by the waste of resources or over-reliance on the input of a single factor. In addition, enterprises can carry out more cooperation with other enterprises, research institutes and universities to promote enterprise innovation through the mechanism of industry-university-research cooperation. Secondly, it should concentrate the equity moderately and optimize the equity structure to form the development mechanism of common supervision, so as to realize the win-win situation of enterprise innovation and development and shareholders' rights and interests protection. Thirdly, it must improve its own management level, learn management concepts from the leading enterprises in the industry, continuously improve the internal management system, optimize the departmental organizational structure, and improve the scientific nature of management decisions.

From the government's point of view, firstly, we should continue to improve the subsidy system and strengthen the supervision of the use of funds and the implementation of R&D projects by enterprises, so as to ensure that government subsidies are fully utilized. Second, the introduction of appropriate policies to create a better market environment for the development of enterprises, to encourage enterprises to rely on their own strength to carry out innovative activities, rather than relying on national fiscal policy subsidies for development, and at the same time, to establish and improve the protection mechanism of enterprise innovation, so as to improve the enthusiasm of enterprise innovation.

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