Research on Financing Efficiency of Photovoltaic Industry Based on Three-stage DEA Model

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Abstract

Based on the Three-stage DEA model, this paper calculates the financing efficiency of China's photovoltaic industry, and uses SFA regression model to eliminate the influence of environmental factors and random noise, so as to make the calculation results more accurate. The results show that: firstly, government subsidies will increase the redundancy of financing investment, while tax return will reduce the redundancy of financing investment; secondly, the financing efficiency of photovoltaic enterprises is mainly restricted by scale efficiency, and most photovoltaic enterprises are in the stage of increasing returns to scale; thirdly, for different types of photovoltaic enterprises, the financing efficiency of photovoltaic product manufacturing enterprises is the fastest. Finally, it puts forward relevant countermeasures and suggestions from the enterprise and government level, so as to provide reference for improving the financing efficiency of China's photovoltaic industry.

Keywords- *Three-stage DEA model；photovoltaic；financing efficiency*

1. INTRODUCTION

Energy is the driving force to promote economic development. With the increasing demand for energy, the scarcity of energy is an urgent problem to be solved in the world, and the development of new energy is a breakthrough to alleviate the current dilemma. By the end of December 2020, the total installed power generation capacity of renewable energy in China has reached 930 million KW, accounting for 42.4% of the total installed capacity, and the development and utilization scale ranks first in the world. The installed capacity of photovoltaic power generation is 250 million KW, ranking first in the world for six consecutive years. The photovoltaic industry has developed rapidly in China in recent years. With the expansion of the scale of the photovoltaic industry, the capital demand of companies in the photovoltaic industry has also increased. Since the national development and Reform Commission of the three ministries proposed to speed up the decline of photovoltaic subsidies in 2018, with the reduction of national subsidies, the funding gap required for the sustainable operation of photovoltaic industry is also increasing, so how to raise funds and how to reasonably allocate and use funds are the key issues that photovoltaic enterprises need to pay attention to at present. Therefore, considering the financing efficiency and its influencing factors of the photovoltaic industry under the government subsidy decline policy, putting forward relevant reasonable suggestions has certain practical significance to help photovoltaic enterprises get rid of financing difficulties as soon as possible.

2. LITERATURE REVIEW

The new energy industry has the characteristics of large initial investment and long recovery cycle, and there are many uncertain factors in the development process. Therefore, new energy enterprises need to manage the quality of financing related activities more scientifically, and financing efficiency can be used as the evaluation standard of the quality of financing related activities. At present, most scholars mainly use DEA related models to measure the financing efficiency in different fields. Firstly, some scholars use the traditional DEA model to measure the financing efficiency in related fields. For example, Anna Shi et al. [1] used BCC model and Malmquist index to measure the financing efficiency of renewable energy industry from the perspective of renewable energy industry, and combined traditional financing loans with various green financing channels for evaluation.

In addition, in order to further the complex relationship between input and output, many scholars

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conduct empirical research by establishing a Two-stage DEA model. For example, Tan Xianhua et al. [2] measured the financing efficiency of Listed Companies in the field of Rural Revitalization based on Two-stage DEA. The results show that the financing efficiency of different companies varies with the nature, industry and listed industry. Finally, the key factors affecting financing efficiency are analyzed by using grey correlation analysis method. Other scholars calculate the financing efficiency in different fields based on the improved super efficiency DEA model. For example, Ke Xu et al. [3] used super SBM DEA model to calculate financing efficiency, integrated internal and external factors to build financing ecological index system, and used entropy weight method to analyze the financing ecology of strategic emerging industries in recent years. The results of literature research show that strategic emerging industries should fully consider the collaborative optimization of endogenous factors and external financing ecology in order to improve financing efficiency.

Finally, Fried et al. [4] constructed a Three-stage DEA model, put all decision-making units under the same external environment and random interference conditions, and re measure them with adjusted input or output variables, so as to obtain more real efficiency of decision-making units. For example, Liu Xun et al. [5] used the Three-stage DEA model to empirically evaluate the financing efficiency of low-carbon enterprises, and considered that scale efficiency is the main factor restricting the overall financing efficiency of enterprises. The research shows that choosing the correct input-output structure and appropriate scale will help to improve the financing efficiency of inefficient enterprises.

To sum up, many achievements have been made in the calculation of financing efficiency, covering new energy industry, low-carbon industry and other fields, but few scholars focus on the research of financing efficiency in the field of photovoltaic industry. The refinement of the research object helps to improve the accuracy of the evaluation results. The Three-stage DEA model eliminates the impact of environmental factors and random noise on the financing efficiency results, and the calculation results are more comprehensive and accurate. In this paper, the photovoltaic industry is divided into three categories according to its main product names for comparative analysis of financing efficiency, and the financing efficiency of photovoltaic industry is analyzed and evaluated from different angles, which has a certain reference significance for improving the financing efficiency of photovoltaic industry.

3. MODEL BUILDING

3.1. The first stage of the model

Since the input is easier to control than the output for photovoltaic enterprises, the input-oriented BCC model is selected, that is, the input is minimized under the condition of constant output level.

The linear programming corresponding to the input oriented BCC model is as follows:

$$\min \theta = \theta^*,\quad s.t.\begin{cases} \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ij}, \\ \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rj} \\ \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \ge 0 \\ i = 1,2,\cdots,m;\ j = 1,2,\cdots,n;\ r = 1,2,\cdots,s \end{cases} \tag{1}$$

In Formula (1), there are n decision-making units, which are recorded as $DMU_j(j=1,2,\cdots n)$; Each decision-making unit has m inputs and s outputs respectively, which are recorded as $x_i(i=1,2,\cdots,m)$,Outputs are recorded as $y_r(r=1,2,\cdots,s)$. Where λ represents the linear combination coefficient between decision units, θ^* represents the minimum efficiency calculated by the model.

3.2. The second stage of the model

The relaxation variables of the input variables obtained in the first stage are decomposed. Fried et al. [4] believe that the relaxation variable can be decomposed into three variables: environmental factors, random noise and management factors. SFA regression is used to eliminate environmental factors and random noise, so as to make the calculation result of financing efficiency more accurate. In the second stage, the input oriented SFA model is constructed, and the equation is as follows:

$$S_{ni} = f(Z_i;\beta_n) + v_{ni} + \mu_{ni};\ i = 1,2,\cdots,I;\ n = 1,2,\cdots,N \tag{2}$$

In Formula (2), S_{ni} represents the slack variable of input i for sample number n in the first stage, Z_i represents the selected environment variable, β_n represents the correlation coefficient corresponding to each environmental variable, $v_{ni}+\mu_{ni}$ represents the mixed error term, v_{ni} represents random dry scanning items, $v_{ni}\sim N\left(0,\sigma_v^2\right)$, μ_{ni} represents the management invalidity item, $\mu_{ni}\sim N^+\left(0,\sigma_\mu^2\right)$. At the same time, it is assumed that v_{ni} and μ_{ni} are independent of each other.

Then adjust the input variables. The adjustment formula is as follows:

$$X_{ni}^{*} = X_{ni} + \left[\max(f(Z_i;\hat{\beta}_n)) - f(Z_i;\hat{\beta}_n)\right] + \left[\max(v_{ni}) - v_{ni}\right]$$
$$i = 1, 2, \cdots, I; n = 1, 2, \cdots, N \quad (3)$$

In Formula (3), X_{ni}^{*} is the adjusted input value; X_{ni} is the initial input value before adjustment; $\left[\max(f(Z_i;\hat{\beta}_n)) - f(Z_i;\hat{\beta}_n)\right]$ is the adjustment of external environmental factors; $\left[\max(v_{ni}) - v_{ni}\right]$ is to adjust the random error.

3.3. The third stage of the model

The adjusted input variable is used to replace the original input, Once again, the BCC model is used for corresponding calculation. This calculation excludes the influence of random noise and environmental factors, and the calculated efficiency value of each enterprise is more objective and accurate.

4. INDICATOR SELECTION AND DATA SOURCE

4.1. Index selection

4.1.1. Input output index selection

Financing can be understood as the funds raised by enterprises, and the optimal financing efficiency can be expressed as a financing arrangement in which enterprises use the lowest funds raised to create the highest benefits for enterprises. Based on the existing literature and following the principles of relevance, simplification and data acquisition, this paper selects the indicators of financing efficiency. This paper comprehensively considers it as an input index from the perspectives of debt financing, equity financing and endogenous financing[5], in which the sum of noncurrent liabilities and short-term loans is taken as debt financing, and interest free operating loans are not considered in debt financing. The sum of paid in capital and capital reserve is regarded as equity financing, while endogenous financing is expressed by the sum of surplus reserve and undistributed profit. The total operating income and earnings per share reflecting the profitability of the enterprise are selected as the output indicators to measure the financing efficiency of the photovoltaic industry.

4.1.2. Selection of indicators of external financing environment for SFA regression

The external environmental variables should be the factors that enterprises cannot control independently but will affect the financing efficiency of enterprises [6]. This paper considers from the perspective of industrial policy and refers to the development process of photovoltaic industry, and selects the two indicators of government subsidies and tax returns received as environmental variables, The government's subsidies and preferential tax policies for the photovoltaic industry will increase the amount of funds available to enterprises, provide a strong guarantee for the smooth development of relevant production and operation activities of photovoltaic enterprises, promote the development of photovoltaic industry, affect the financing needs of enterprises, and have a certain impact on the allocation and utilization efficiency of existing financing funds of enterprises.

4.1.3. Data source and sample selection

This paper selects the representative listed companies in the photovoltaic concept section of flush financial website, which mainly focus on photovoltaic business or the proportion of photovoltaic business has increased rapidly in recent years. It does not include ST or * ST, companies listed after 2015 and incomplete data disclosure. The original data comes from the financial reports of listed companies and CSMAR database. Finally, 65 qualified listed companies are selected as samples.

When DEA method is used for calculation, all data are required to be positive. Since the selected indicators have negative values, all indicators are dimensionless. The standardized formula is:

$$x_{ij} = 0.1 + 0.9 * \frac{(x_{ij} - x_{\min})}{(x_{\max} - x_{\min})} \quad (4)$$

In Formula (4), $x_{\max}$ and $x_{\min}$ represent the maximum and minimum values of indicators respectively.

5. EMPIRICAL ANALYSIS

5.1. Phase I analysis

Based on the above indicators, deap2.1 software is used to calculate the financing efficiency of photovoltaic industry. The results are shown in Table 1. According to the calculation results of the first stage, the average comprehensive efficiency of the financing efficiency of the photovoltaic industry in recent five years is 0.761, and there is still much room for improvement. From the annual average value, the fluctuation range of the average value of scale efficiency is greater than that of pure technical efficiency. In 2017, the average value of the three efficiency of financing efficiency of photovoltaic industry reached the best.

TABLE 1. AVERAGE VALUE OF OVERALL FINANCING EFFICIENCY OF PHOTOVOLTAIC LISTED COMPANIES IN THE FIRST STAGE FROM 2015 TO 2019.

year	Average value of comprehensive efficiency	Mean value of pure technical efficiency	Mean scale efficiency

2015	0.653	0.875	0.756
2016	0.721	0.874	0.826
2017	0.831	0.886	0.939
2018	0.798	0.873	0.917
2019	0.803	0.883	0.912
Five year average	0.761	0.878	0.87

5.2. Second stage SFA regression

According to the calculation results of the first stage, SFA regression is carried out using frontier 4.1 software. The calculation results are shown in Table 2 below. If the value of γ is greater than 0.9, it indicates that there are great differences in the management efficiency of different listed companies, and the SFA regression is reasonable. Overall, the LR test of each input redundancy is significant at the 1% level, indicating that the environmental variables selected in this paper have a significant impact on the financing efficiency of listed companies.

TABLE 2. SFA REGRESSION RESULTS IN THE SECOND STAGE.

variable	Slack variable coefficient of debt financing	Relaxation variable coefficient of equity financing	Endogenous financing relaxation variable coefficient
Constant term	-0.033***(0.009)	-0.023***(0.009)	-0.010(0.007)
government grants	0.100**(0.039)	0.079*(0.045)	0.004(0.043)
Refunds of taxes	-0.027(0.018)	-0.041*(0.021)	-0.023(0.018)
σ^2	0.016***(0.003)	0.018***(0.003)	0.014***(0.003)
γ	0.907***(0.018)	0.925***(0.015)	0.915***(0.019)
LR inspection	528.490***	499.852***	341.078***

Note: standard error is in brackets.

From the regression results, on the whole, the regression coefficient of government subsidies on the relaxation variables of the three financing methods is positive, while the regression coefficient corresponding to tax preference is negative. This shows that the increase of government subsidies increases the input redundancy of enterprise financing, is not conducive to the improvement of enterprise financing efficiency, and has a more obvious adverse impact on debt financing and equity financing. The tax relief tools used by the government for the photovoltaic industry can reduce the redundancy of financing and investment of photovoltaic listed companies, and enterprises can make better use of financing funds after obtaining tax incentives, so as to improve financing efficiency. Therefore, in areas with more government subsidies, enterprises should pay more attention to the allocation and use efficiency of funds to avoid resource waste.

5.3. The third stage: the empirical results of the adjusted DEA model

Once again, deap2.1 software is used to calculate the financing efficiency of photovoltaic industry. The specific results are shown in Table 3 below.

TABLE 3. AVERAGE VALUE OF OVERALL FINANCING EFFICIENCY OF PHOTOVOLTAIC LISTED COMPANIES IN THE THIRD STAGE FROM 2015 TO 2019.

year	Average value of comprehensive efficiency	Mean value of pure technical efficiency	Mean scale efficiency
2015	0.663	0.932	0.717
2016	0.674	0.933	0.725
2017	0.865	0.943	0.919
2018	0.854	0.939	0.912
2019	0.819	0.944	0.87
Five year average	0.775	0.938	0.828

5.3.1. Analysis of overall financing efficiency

From 2015 to 2019, the average annual pure technical efficiency of the photovoltaic industry in the third stage has improved, and the adjusted average annual scale efficiency has decreased. This shows that the low management efficiency of most photovoltaic enterprises is caused by poor environmental conditions and large random noise. The average comprehensive efficiency from 2015 to 2019 is 0.775, and there is still room for improvement. After the third stage adjustment, the annual average value of financing efficiency and pure technical efficiency of photovoltaic industry fluctuates between 0.9-1, indicating that the management level of photovoltaic enterprises is good and stable. The annual average value of scale efficiency and comprehensive efficiency of financing efficiency of photovoltaic industry fluctuates between 0.6 ~ 0.95, with large fluctuation and consistent trend. It is pointed out that the main factor restricting the improvement of financing efficiency of photovoltaic industry is scale efficiency.

5.3.2. Return to scale analysis

The specific scale income of photovoltaic enterprises is shown in Table 4. From 2015 to 2019, most photovoltaic enterprises are in the state of increasing returns to scale, and less than 20% of photovoltaic enterprises have achieved ideal returns to scale, which indicates that the overall financing efficiency of the photovoltaic industry has not reached the ideal state, most enterprises have insufficient funds or insufficient use of funds, and it is difficult to achieve returns to scale due to their own scale constraints. Enterprises with increasing returns to scale should expand financing scale in order to improve financing efficiency and market competitiveness. However, blindly expanding the scale of financing is also undesirable. Enterprises with diminishing returns to scale should pay attention to the matching of financing scale with their own management level and technical level, reasonably allocate the funds integrated into the enterprise, and give full play to the advantages of the enterprise.

TABLE 4. RETURNS TO SCALE OF PHOTOVOLTAIC ENTERPRISES FROM 2015 TO 2019.

	2015	2016	2017	2018	2019
IRS	56(86.1%)	59(90.8%)	48(73.8%)	45(69.2%)	48(73.8%)
DRS	2(3.1%)	0(0%)	8(12.3%)	12(18.5%)	5(7.7%)
CRS	7(10.8%)	6(9.2%)	9(13.9%)	8(12.3%)	12(18.5%)

Note: IRS means increasing returns to scale, DRS means decreasing returns to scale, and CRS means unchanged returns to scale

5.3.3. Analysis on financing efficiency of different types of photovoltaic listed companies

According to the main business product names and specific instructions of photovoltaic listed companies on flush website, they are divided into three categories: photovoltaic related product manufacturers, photovoltaic power station investment and operation enterprises and comprehensive enterprises involved in both. The comparative analysis of the financing efficiency of the three types of enterprises is conducive to further analyze the financing efficiency of different types of enterprises in the photovoltaic industry.

Among them, pure technical efficiency refers to the production efficiency affected by enterprise management level, technical level and other factors. As can be seen from Figure 1, overall, the management efficiency of fund use and distribution of each company is effective and stable. Among them, the pure technical efficiency of photovoltaic product production enterprises has been stable at the highest level for five years, followed by comprehensive enterprises, and the pure technical efficiency of photovoltaic power station investment and operation enterprises is the lowest. This shows that the investment and operation business of photovoltaic power station has the characteristics of long investment recovery cycle, and the daily management and operation process are more complex. Therefore, these enterprises need to strengthen management in order to improve their financing efficiency.

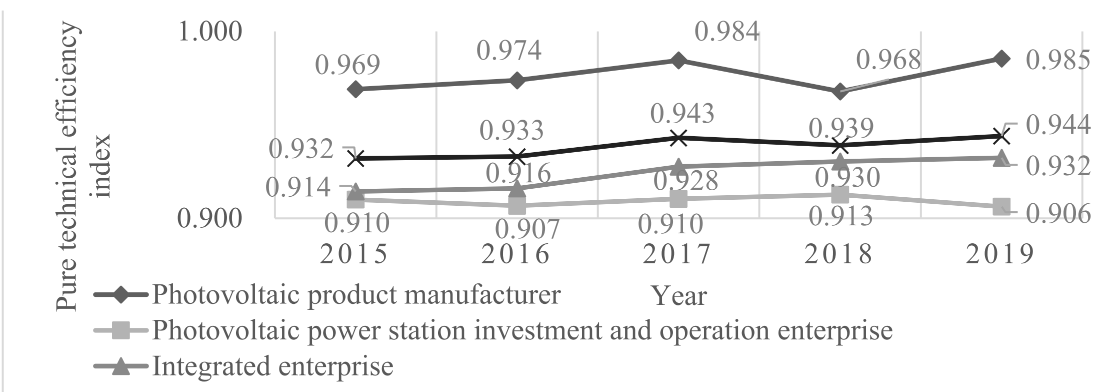

Fig.1 evaluation results of pure technical efficiency of PV listed companies after adjustment

Scale efficiency reflects the distance between the existing scale and the optimal scale. As can be seen from Figure 2, the scale efficiency of the three types of photovoltaic listed companies shows a trend of first rising and then falling, and fluctuates greatly. In contrast, the scale efficiency of integrated enterprises in 2015-2016 is better than that of the other two types of photovoltaic enterprises, and the scale efficiency of each company is closer after 2017. From the overall development trend, the scale efficiency of financing efficiency of companies has developed rapidly, but it has shown a downward trend in the last year. Photovoltaic companies need to appropriately adjust the company scale according to the business type, improve the financing efficiency, make full use of the raised funds and create greater benefits for the enterprise.

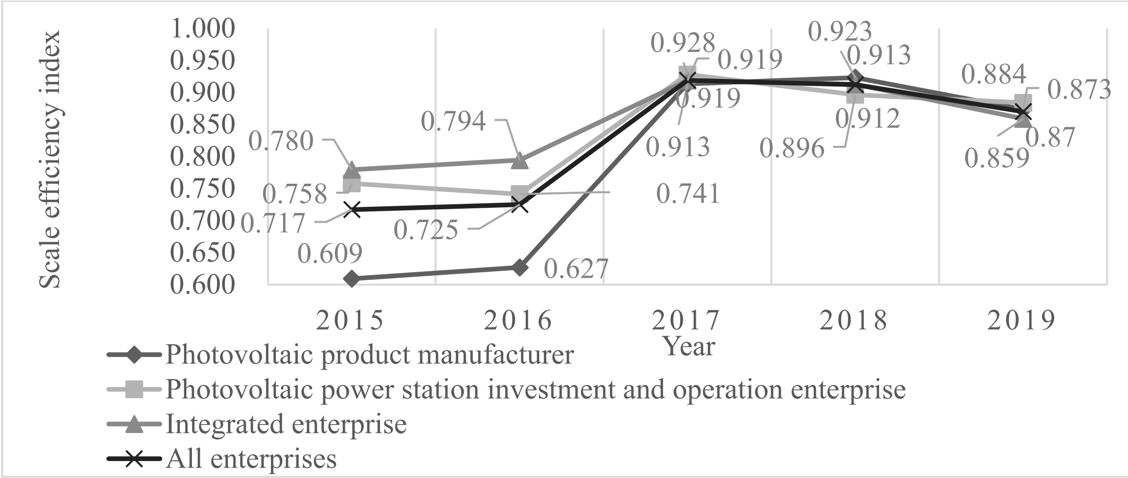

Fig.2 evaluation results of scale efficiency of PV listed companies after adjustment

Comprehensive efficiency is a comprehensive evaluation of the financing capacity, scale level and management level of decision-making units. As can be seen from Figure 3, the overall efficiency of financing efficiency of photovoltaic enterprises after adjustment shows a trend of first rising and then falling. The average comprehensive efficiency of the overall financing efficiency of enterprises fluctuated between 0.5-0.9 in recent five years, peaked in 2017, and there is still room for improvement. In contrast, photovoltaic product manufacturers have developed rapidly in the past three years, and their financing efficiency has been significantly improved, exceeding the average level of the other two types of photovoltaic enterprises. To sum up, the improvement of financing efficiency of photovoltaic production enterprises mainly benefits from its stable management level and more reasonable scale expansion.

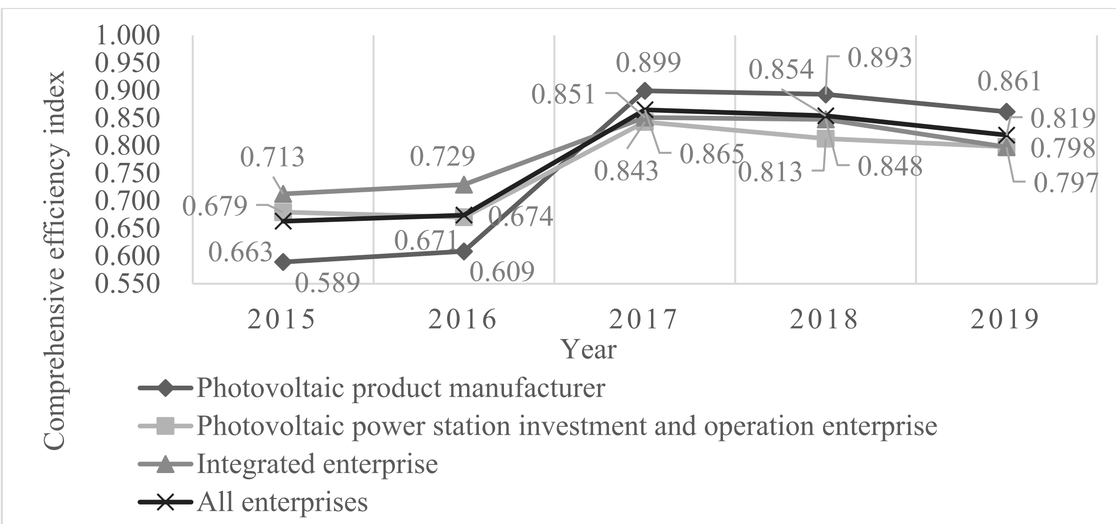

Fig.3 comprehensive efficiency evaluation results of PV listed companies after adjustment

6. CONCLUSIONS AND RECOMMENDATIONS

This paper uses the Three-stage DEA method to calculate the financing efficiency of the photovoltaic industry from 2015 to 2019, and draws the following conclusions: Firstly, the financing efficiency of the photovoltaic industry is greatly affected by external environmental factors. The increase of government subsidies will aggravate the redundancy of financing and investment of photovoltaic enterprises, which is not conducive to the rational use of enterprise funds. The increase of tax return will reduce the redundancy of financing investment, so as to improve the rational allocation efficiency of financing funds. Secondly, the financing efficiency of China's photovoltaic industry generally has a good level of fund management, and the improvement of comprehensive efficiency is mainly restricted by scale efficiency. Finally, from the classification of photovoltaic enterprises, the financing efficiency of photovoltaic related product manufacturing enterprises has improved rapidly, mainly due to their good fund management level and reasonable expansion of financing scale.

In order to effectively improve the financing efficiency of photovoltaic industry, based on the above conclusions, the following suggestions are put forward:

from the enterprise level, firstly, photovoltaic enterprises need to improve the financing scale in order to achieve the best scale income. Photovoltaic enterprises need to constantly try diversified financing channels to steadily improve financing efficiency. Secondly, photovoltaic enterprises need to standardize the management of their own financing activities. For photovoltaic power station investment and operation enterprises with long investment payback period and high technical level, they must improve their own fund management level and technical level, and strive to build an efficient financing system suitable for the enterprise itself.

From the perspective of the government, the government should gradually explore and improve the relevant systems of government subsidies to support the healthy development of photovoltaic industry. Because preferential tax policies can promote the improvement of financing efficiency of photovoltaic industry. When subsidizing photovoltaic enterprises, the government should improve the corresponding review and supervision system, promote enterprises to make rational use of financial funds and avoid resource waste. Finally, China also needs to constantly improve its own capital market, provide richer financing methods for the photovoltaic industry, and develop in continuous exploration and innovation.

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