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Sustainable Financing Efficiency and Environmental Value in China's Energy Conservation and Environmental Protection Industry under the Double Carbon Target

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Abstract: Difficulty in financing and low financing efficiency is one of the bottlenecks that restrict the high-quality development of China's energy-saving and environmental protection industry and economy. The key to improving financing efficiency is to understand its influencing factors. This paper uses data envelopment analysis (DEA) and the Malmquist index to measure the overall financing efficiency and the efficiency of different financing methods of 205 Chinese energy-saving and environmental protection industries from 2015 to 2020 from static and dynamic perspectives, respectively, as well as the Tobit model to estimate the impact of factors such as the digital transformation and green technological innovation of enterprises on financing efficiency. The study shows the following: (1) Static analysis shows that: the financing efficiency of the comprehensive technical efficiency of China's energy conservation and environmental protection industry is less than one, 5.8% to 23.41% of enterprises have very effective comprehensive technical financing efficiency, and fewer than 9% enterprises have very effective scale efficiency levels. Enterprises may have more room for improving their financing efficiency in the future. The four types of financing are, namely, internal financing, equity financing, fiscal financing, and debt financing, in descending order of efficiency. (2) Dynamic analysis shows that the financing efficiencies of debt financing and fiscal financing are both on an upward trend, while internal and equity financing efficiencies are on a downward trend. Additionally, the technological progress change index and scale efficiency are two key factors affecting the financing efficiency of different financing methods. (3) In terms of financing methods, the comprehensive technical efficiency and scale efficiency of endogenous financing and equity financing are high, while the comprehensive technical efficiency and scale efficiency of debt financing and fiscal financing are low and flat. (4) Digital transformation, green technology innovation, the asset–liability ratio, profitability, and operational capability have a significant positive impact on the financing efficiency of energy-saving and environmental protection enterprises. This paper studies the financing efficiency of China's energy conservation and environmental protection industry under different financing methods and the mechanism through which key factors affect the financing efficiency of enterprises. It aims to provide a theoretical basis for managing financing methods scientifically and rationally and improving the financing efficiency of the energy conservation and environmental protection industry, as well as to provide practical reference for the implementation of digital transformation, green technology innovation and diversified financing in China and other developing economies.

Keywords: environmental value; financing efficiency; DEA model; Tobit model; financing methods

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1. Introduction

Improving the efficiency of resource use and protecting and managing the ecological environment is a recurrent theme of worldwide concern [1–4] and one of the issues that needs to be addressed for China's high-quality economic development. With increasing environmental pollution and the depletion of non-renewable energy sources, China is paying increasing attention to the synergy between environmental quality and economic development and has always attached great importance to energy conservation and environmental protection [5,6]. During the 12th Five-Year Plan, the energy conservation and environmental protection industry was listed as one of the emerging strategic industries in order to promote ecological development and improve energy use efficiency [7]. During the 13th Five-Year Plan, the State issued a strategic plan for the development of the energy conservation and environmental protection industry that clearly defined the direction of the industry and provided policy support to accelerate the development of the energy conservation and environmental protection industry into a leading industry in the country's economic development [8]. During the 14th Five-Year Plan period, China will support green technological innovation, continue to cultivate and grow the energy conservation and environmental protection industry, and strengthen the strategic support of green and low-carbon strategies for high-quality economic development. In March 2021, at the ninth meeting of the Central Finance and Economics Commission, China incorporated carbon peaking and carbon neutrality into the plan for ecological and environmental construction, pointing out the direction for green and low-carbon development. Energy-saving and efficiency, environmental protection, and low-carbon strategies are the only way to achieve carbon peaking and carbon neutrality; in this context, energy-saving and environmental protection enterprises are ushering in a new round of an important window period. Energy-saving and environmental protection enterprises are expected to usher in good development opportunities.

China's energy-saving and environmental protection industry saw rapid development in the first quarter of 2022, with an output value of over RMB 8 trillion and an annual growth rate of over 10% [9]. However, some sources show that from 2016 to 2019, the average operating profit margin of environmental protection enterprises fell from 14% to around 10%, mainly due to vicious competition at low prices triggered by the homogenization of environmental protection products and services [10]. On the one hand, due to information asymmetry, it is difficult for energy-saving and environmental protection enterprises to finance the funds needed for technological innovation, and, on the other hand, due to the existence of internal management and technical problems, the lack of operational capacity and the profitability of enterprises, and the lack of a long-term mechanism for using the funds, among other reasons, it is also difficult for enterprises to absorb the funds raised. Difficulties in financing and the low efficiency of financing are some of the bottlenecks limiting high-quality economic development [5]. As energy-saving and environmental protection enterprises are asset-intensive industries with high technological content, long return cycles, low yields, and high investment risks, they generally suffer from low financing efficiency [11]. In order to achieve the goal of double carbon and the high-quality development of the energy-saving and environmental protection industry, the problem of low efficiency needs to be solved. To this end, it is important to study the financing efficiency of the energy efficiency and environmental protection industry.

As the main basis for objectively evaluating the quality of financing for the entire industry, optimizing and improving the efficiency of financing is of great significance to ensure the high-quality development of the energy-saving and environmental protection industry. However, due to the long investment return cycle, high investment risks, and technical barriers, the current shortage of funds and financing bottlenecks in the energy-saving and environmental protection industry are more prominent and restrict its high-quality development. The current situation of financing is mainly manifested as follows: first, the financing channels are poor, and the scale of financing is limited. In other words, the domestic energy-saving and environmental protection industry has difficulties in meeting its own financing needs due to the dual constraints of imperfect direct financing mechanisms and restricted indirect financing channels. Secondly, although external financing for China's energy-saving and environmental protection industry is growing at a relatively fast pace, gradually forming financing through both equity and debt channels, the funds still cannot easily meet the needs of the energy-saving and environmental protection industry's development, and there are limitations in the use of state funds and foreign capital, which seriously restrict financing efficiency. Thirdly, on the one hand, it is difficult to attract external investors due to the characteristics of the energy-saving and environmental protection industry (large investments, long cycles, and high risk) and the existence of information asymmetry; on the other hand, energy-saving and environmental protection enterprises lack core competitiveness and have a weak capital allocation capacity, making it difficult to make the most effective use of the funds.

This study analyzes the impact of internal factors on the financing efficiency of energy-saving and environmental protection enterprises in order to build core competitiveness through digital transformation and green technology innovation in the energy-saving and environmental protection industry, to improve financing efficiency, and to attract more external investment through improvements to the enterprises' reputations, leading to the high-quality development of the energy-saving and environmental protection industry and the early achievement of the double carbon policy. This will in turn attract more external investment through the reputation mechanism, drive the high-quality development of the energy-saving and environmental protection industry, and achieve the double carbon target as soon as possible. Additionally, this article also provides ideas that other developing countries can build upon to develop their energy-saving and environmental protection industries and provides multiple financing sources.

The rest of this article is organized as follows. Section 2 is the literature review. Section 3 is the model and data sources. Section 4 is the empirical results and analysis. Section 5 is the conclusion and recommendations for further study.

2. Literature

2.1. Finance Theory

Research on financing in foreign countries has previously been carried out, and the financing theories represented by the modified MM theory, the tradeoff theory, and the sequential financing theory were formed. Modigliani and Miller (1963) introduced enterprise income tax into the MM theory and proposed the modified MM theory [12]. According to this theory, debt financing can significantly increase the value of the enterprise. With higher debt financing, income tax expenditure can be reduced to a greater extent, the weighted average cost can be reduced, and the value of the enterprise can be improved. Robichek (1967) proposed the tradeoff theory, which suggests that although the asset–liability ratio could offset the corporate income tax and reduce the agency cost of corporate equity, the greater the asset–liability ratio, the better, i.e., the higher the debt-to-asset ratio, the higher the cost of bankruptcy. The trade-off theory considers the benefits and costs brought by debt, and the marginal benefit of increasing liability tax shield and the marginal cost of increasing liability default jointly determine the financing structure. This requires enterprises to weigh the tax shield income brought by debt and the cost of financial risk caused by debt when determining the financing structure. In 1984, Myers et al. proposed the sequential financing theory based on capital structure theory [13]. According to this theory, enterprises will make choices in the order of internal financing, debt financing, and equity financing when choosing financing methods. Financing theories have been extensively researched overseas, and the continuous evolution and improvement of financing theories has provided a certain theoretical basis for the study of financing efficiency.

Domestic scholars have carried out research on financing, which firstly revolves around the definition of financing. The connotations of financing efficiency are defined in terms of financing capacity, costs, and benefits. In terms of financing capacity, Gao (2000), in the process of evaluating China's financial efficiency, mentions that financing efficiency can be judged in terms of the size of financing capacity [14]. Liu (2000), based on summarizing the importance of financing in economic development, points out that financing efficiency refers to the size of the financing capacity presented by enterprises in the process of economic development [15]. Gao (2005) believes that the efficiency of corporate financing is specifically expressed in terms of financing capacity [16]. In terms of costs and benefits, Song (1998) uses economics as a research perspective and divides financing efficiency into two aspects: transaction efficiency, which is the ability to incorporate the required funds at the lowest cost, and allocation efficiency, which is the ability to optimize the use of funds [17]. Wei (2001) argues that financing efficiency is the ratio of financing costs to financing benefits for a firm within a certain spatial and temporal boundary [18]. According to Zhang and Zhao (2015), financing efficiency refers to the cost paid by a firm in the process of financing and the benefit obtained [19]. Wu and Huang (2021) define financing efficiency as the ability of a firm to raise capital at the lowest cost and risk and the ability to use it to maximize returns for the firm [20]. Wei and Geng (2022) classify financing efficiency according to two aspects: the efficiency of raising capital and the efficiency of allocating capital [21].

Domestic scholars have conducted in-depth research on the connotations of financing efficiency from different perspectives, providing a theoretical basis for defining the connotations of financing efficiency in this paper. This paper takes the view that financing efficiency refers to the ability of enterprises to obtain funds at low cost and to use the incorporated funds efficiently.

2.2. Financing Efficiency Measures

Scholars mainly use the DEA (the date envelopment analysis method) and Malmquist models, the entropy weight method, the Super-SBM method, and the data envelopment method to measure and analyze financing efficiency. (1) The DEA model: Charnes and Cooper et al. proposed the DEA model in 1978 [22]. As the model can deal with boundary efficiency, some scholars have gradually begun to use this model to solve the problem of measuring the efficiency of multiple inputs and multiple outputs. For example, Luoma et al. (1996) used the data envelope method to calculate the production efficiency of Finnish health centers and used the Tobit model to analyze how economic, structural, and demographic factors affect efficiency [23]. Das and Ghosh (2006) estimated the technical efficiency of commercial banks in India using the DEA method [24]. Lebovics and Hermes et al. (2016) measured the financial and social efficiency of micro-institutions in Vietnam based on a DEA model [25]. Amowine et al. (2019) used a DEA model to assess the dynamic energy efficiency of African economies to identify potential areas where inefficiencies occur [26]. (2) The DEA–Malmquist index model: To further improve the DEA model, Fare et al. (1998) introduced the Malmquist index into the DEA model to form the DEA–Malmquist dynamic model, which overcomes the limitation of the DEA only being able to be used for static analysis, and this has now become the main method for measuring efficiency [27]. For example, Min and Ahn (2017) used DEA and the Malmquist productivity index to study the efficiency of the US public transport system [28]. Amado and Barreira et al. (2019) used the DEA and Malmquist indices to calculate the quality of life in each city, comparing the differences in quality of life between groups of cities with decreasing and increasing populations, using Portuguese mainland cities as a study sample [29]. Singh and Bala et al. (2021) measured the efficiency of the healthcare system in the ASEAN region using DEA–Malmquist and found that the inefficiency of the healthcare system in the region affected the healthy and stable development of the healthcare system in the region [30]. (3) The entropy power method: Zhang et al. (2009) used the entropy power method to analyze the financing efficiency of private information enterprises and found that the financing efficiency of private information enterprises in China was low [31]. Fan et al. (2012) used the entropy power method to measure the financing efficiency evaluation system with mining enterprises as the research object, and the results showed that the overall financing efficiency of mining enterprises in China was not high [32]. The results show that the overall financing efficiency of mining enterprises in China is not high. Chen et al. (2013) established a financing efficiency evaluation system using the three dimensions of financing cost, risk, and economic scope, and determined the financing efficiency of a technology-based enterprise through the entropy weight method. The study found that the financing efficiency of this technology-based enterprise was high [33]. Wang et al. (2016) used the Super-SBM method to measure the financing efficiency of the new-energy automobile industry and found that the financing efficiency of the industry was low, with the low pure technical efficiency being the main reason for the low financing efficiency of the industry [34]. (4) The Super-SBM model: Yan (2020) used the Super-SBM method to evaluate the financing efficiency of the artificial intelligence industry, and the study found that the financing efficiency of the industry was generally low [35]. He (2016) used the data envelopment method to analyze two sets of sample data of GEM-listed enterprises, and the study found that the sample enterprises had the problem of low financing efficiency; the author suggested improving financing efficiency in terms of improving management and making full use of the integrated capital [36]. Wu et al. (2019) used the data envelopment analysis method to analyze the financing efficiency of SMEs on the New Third Board by year and industry and found that the financing efficiency of the sample enterprises was low overall and could be improved through technological innovation [37].

2.3. Factors Influencing the Efficiency of Financing

Research on the factors influencing the efficiency of financing can be divided into macro and micro factors, as well as other aspects of industry.

At the macro level, Cardone et al. (2005) argue that firms are vulnerable to financing constraints in the financing process and that financing efficiency can be improved by working with many financial entities and maintaining relationships over a longer period [38]. Ngoc et al. (2009) found that when firms have good network relationships with banks, they can effectively increase the transparency of information between the financing parties, which is conducive to improving the efficiency of financing [39]. Lu et al. (2015) found that the national energy development strategy, the macroeconomic environment, and the level of the development of the energy and financial markets are the key factors affecting the financing efficiency of energy efficiency and environmental protection enterprises [40].

At the micro level, Stulz (1990) argues that reducing the agency costs of managerial discretion can help to improve the efficiency of corporate finance [41]. Luis and Sarah (2018) argue that energy costs can effectively improve financing efficiency [42]. Bo et al. (2013) argue that the perceived risk and transaction costs of energy efficiency projects in green energy firms can affect financing efficiency and that firms should reduce the perceived risk and transaction costs of energy efficiency projects to mitigate the possible negative effects of inefficient financing on firm development [43]. The perceived risks and transaction costs of energy efficiency projects should be reduced in order to weaken the negative effects of inefficient financing on enterprise development. Foreign scholars have explored the factors affecting financing efficiency from different perspectives, providing research ideas for this paper, and allowing us to construct a model of financing efficiency impact factors.

At the industry level, research is mainly focused on strategic emerging industries and technology-based enterprises, for example, in order to explore the factors affecting the financing efficiency of strategic emerging industries in the Beijing–Tianjin–Hebei region, Zeng and Geng (2018) selected external variables from the perspectives of labor, capital, and technology [44]. The study found that the GDP growth rate and technology market turnover were positively related to the financing efficiency of the industry. Zeng and Geng (2019) found that a lower shareholder equity ratio and gearing ratio can effectively improve financing efficiency, while a higher ratio of illiquid shares inhibits financing efficiency, given a constant internal and external environment in strategic emerging industries [45]. Wang and Dong (2020) explored the factors affecting the financing efficiency of technology-based enterprises and found that profitability, growth capability, gearing ratio, operational capability, and the percentage of skilled employees can affect the financing efficiency of these enterprises [46]. Gu and Bian (2020) measured the financing efficiency of technology-based enterprises in China based on the DEA model and found that a technology–finance coupling synergy could improve financing efficiency by reducing the financing cost of enterprises [47].

Relatively little research has been completed on the efficiency and factors influencing the financing of energy-saving and environmental protection enterprises. Zhang and He (2013) randomly selected 30 energy-saving and environmental protection enterprises as research subjects and used the data envelopment method to measure the financing efficiency. They found that the financing efficiency of energy-saving and environmental protection enterprises in China has been declining year by year due to the low level of technology. The data envelope method was used to measure the financing efficiency of 30 energy-saving and environmental protection enterprises. To further explore the drivers of the decline in financing efficiency, a theoretical analysis of the quality of financing and the level of hardware as intrinsic factors affecting the decline in technology level was conducted [48]. Dong (2015) presented financial scale, financial structure and financial efficiency as key factors for providing financial support for the development of energy conservation and environmental protection industries [49]. Xie and Ma (2016) used 18 energy-saving and environmental protection enterprises in the western region of China as the research object, and found that the profitability, company size, financing structure, and capital utilization rate of the energy-saving and environmental protection enterprises in the western region were negatively related to financing efficiency, and the age of listing was positively related to financing efficiency [50]. Pan et al. (2016) examined the trend of financing efficiency in the environmental industry from 2009 to 2013. The results showed that financing efficiency follows a downward trend. The financing efficiency of environmental firms is positively correlated with firm size, firm quality and GDP, and negatively correlated with corporate bond financing, majority shareholder ownership and CPI [51]. Huang and Wen (2017) studied the rate of financial support for the energy conservation and environmental protection industry and its influencing factors [52]. Yang and Zhang (2019) studied the impact of debt financing on R&D investment in companies listed as energy-saving and environmental protection enterprises [11]. Yi et al. (2020) researched the level of digitization and intelligence in the environmental protection industry, and the results of the supply chain recovery after COVID-19 suggest that the financing efficiency of environmental companies is at a low level and that the level of technology does not meet the needs of further development [53]. Wei and Geng studied the impact of environmental regulation on financing efficiency in the clean energy industry and found a U-shaped relationship between environmental regulation and financing efficiency, with the nature of the SOEs and internal controls weakening the U-shaped effect [54]. Geng and You (2021) examined the impact of the financing environment on the energy efficiency and environmental protection industry [21].

In summary, we found that, although scholars at home and abroad have achieved fruitful results in their research on financing efficiency, there is still room for further research. Scholars at home and abroad have extensively studied the connotations of financing efficiency, but have not yet formed a consistent academic view; in terms of the research object of the financing efficiency of energy-saving and environmental protection enterprises, there is a relative lack of research on this topic. Although scholars have explored the influencing factors of the financing efficiency of different enterprises, research on the influencing factors of the financing efficiency of energy-saving and environmental protection enterprises only examines influencing factors from a broad adaptation perspective, resulting in a lack of targeted research. In the context of carbon peaking and carbon neutrality, improving financing efficiency is a prerequisite for the green and low-carbon transformation and development of energy-saving and environmental protection enterprises. To this end, this paper defines the concept of financing efficiency based on resource allocation theory, uses data envelopment analysis to measure financing efficiency, and comprehensively analyzes the current situation of financing efficiency of energy-saving and environmental protection enterprises from both static and dynamic perspectives, with a focus on the static financing efficiency of financing methods. Based on the internal influencing factors of energy-saving and environmental protection enterprises, we selected the factors of enterprise size, digital transformation, green technology innovation, asset–liability ratio, profitability, and operational capacity to establish a model of the influencing factors of financing efficiency. We used the Tobit method to conduct a regression analysis on the model of the influencing factors of financing efficiency.

3. Methods and Materials

3.1. Methods

3.1.1. DEA Model

The data envelopment analysis (DEA) was developed by Chauncey and Cooper et al. in 1978 and is a non-parametric method for measuring the relative efficiency values of multiple input decision units and output decision units. The basic principle is to use input and output indicators as variables, apply a mathematical and statistical model to select a frontier consisting of relatively optimal input–output combinations, compare the decision units with the frontier, and measure the efficiency values according to the degree of deviation [55]. The DEA model is objective, easy to operate, and practical, and has become the main method of efficiency assessment. In the process of application, two representative models of the DEA are the constant payoff to scale (CRS) and the variable payoff to scale (VRS) models. The CRS model was created in 1978 by Charnes, Cooper, and Rhodes, renowned American operations researchers, and is a systematic evaluation method that is input-oriented and assumes constant returns to scale. To further refine the application of the DEA model, Banker, Charnes, and Cooper expanded the DEA model in 1984 to form the VRS model, which assumes variable returns to scale, i.e., unequal efficiency for the same proportion of input-oriented and output-oriented values, and allows efficiency to be discussed separately when calculating efficiency. As the development of Chinese enterprises is inextricably linked to national macroeconomic policies, the payoffs to scale often fluctuate, making the CRS model inapplicable in this context [56]. In contrast, the VRS model is more commonly used in enterprise efficiency measurement; additionally, energy-saving and environmental protection enterprises are capital-intensive enterprises, and the input indicators are more affected by economic changes, and the changes in efficiency are also greater. Therefore, we used the VRS model with variable returns to scale to measure the financing efficiency of energy-saving and environmental protection enterprises. Assuming that there are n energy-saving and environmental protection enterprises, i.e., n decision units, with m input variables and s output variables in each decision unit, the model can be expressed as Equation (1):

$$rj\begin{cases} \min[\theta - \varepsilon(\sum\limits_{i=1}^{m} s_i^- + \sum\limits_{r=1}^{s} s_r^+)] \\ s.t. \sum\limits_{j=1}^{n} y_{ij}\lambda_j + s_i^- = \theta x_{xj0}, i \in (1,2,\ldots,m) \\ \sum\limits_{j=1}^{n} y\ \lambda_j - s_r^+ = \theta y_{rj0}, r \in (1,2,\ldots,s) \\ \sum\limits_{j=1}^{n} \lambda_j = 1 \\ \theta, \lambda_j, s_i^-, s_r^+, \geq 0, j = 1,2,\ldots,n \end{cases} \quad (1)$$

In the model, the effective value of the evaluated decision unit is expressed as θ, the input slack variable is expressed as s_i^-, the output slack variable is expressed as s_r^+, the weight variable is expressed as λ_j, the input i of the j_0 decision unit is expressed as x_{ij_0}, and the output r of the j_0 decision unit is expressed as y_{rj0}.

3.1.2. Malmquist Index Model

The Malmquist index portrays the changes in the total factor efficiency from a dynamic perspective, providing a description of the dynamic changes in the production efficiency of each decision unit over different periods and facilitating a comprehensive understanding of the changes in efficiency by the relevant decision makers. From an output perspective, the index of the total factor productivity change can be expressed as Equation (2):

$$Tfpch = Techch \times Effch \tag{2}$$

$Tfpch$ denotes the total factor productivity change index, which reflects the change in the total factor productivity of the decision unit over time. *Techch* denotes the index of change in technological progress, which reflects the extent to which the technological frontier has been pushed. $Effch$ is an index of change in technical efficiency, which reflects the ability to maximize the use of the existing level of technology by coordinating the various input resource factors at the current level of technology. In the context of variable returns to scale, the technical efficiency change index ($Effch$) can be decomposed into a pure technical efficiency change index (*Pech*) and a scale efficiency change index (*Sech*). The pure technical efficiency index (*Pech*) mainly considers the impact of differences in technology and management capabilities on efficiency, and reflects the level of efficiency achieved by a company making full use of production technology. The index of change in scale efficiency (*Sech*) refers to the degree of deviation of the actual scale from the optimal scale and can reflect, to a certain extent, the extent to which the input and output of resources are consistent with the maximization of returns. Thus, the index can be further expressed as:

$$Tfpch = Techch \times Pech \times Sech \tag{3}$$

3.1.3. Tobit Model

To address the financing efficiency of the energy conservation and environmental protection industry, it is also necessary to explore in depth the factors that affect financing efficiency enhancement. Therefore, we used the Tobit model to analyze the factors that affect the financing efficiency of the energy-saving and environmental protection industry in order to provide empirical data for the formulation and implementation of future energy-saving and environmental protection policies.

Tobit regression models can be used to solve problems where the explanatory variables are restricted to a certain range. As the explanatory variables are between 0 and 1, they are restricted variables, and using least squares to regress the model will lead to biased results. The Tobit model is shown in Equation (4) below.

$$Y_{\mathrm{i}} = \beta_0 + \beta^T X_i + \varepsilon (i = 1, 2, \ldots, m) \tag{4}$$

In the model, the explained variable is expressed as Y_i, i.e., the financing efficiency of energy-saving and environmental protection enterprises. The explanatory variable is expressed as X_i, i.e., the factors that affect the financing efficiency of energy-saving and environmental protection enterprises. The requested parameter variable is expressed as β^T. The parameter error term is expressed as ε.

To address the financing efficiency of the energy conservation and environmental protection industry, in addition to analyzing it, it is also necessary to explore in depth the factors that enhance financing efficiency. Therefore, this paper uses the Tobit model to analyse the factors that affect the financing efficiency of the energy-saving and environmental protection industry in order to provide empirical data for the formulation and implementation of future energy-saving and environmental protection policies.

3.2. Materials

3.2.1. Selection of Evaluation Indicators

A reasonable selection of the evaluation indicators is a prerequisite and basis for effectively calculating the financing efficiency of energy-saving and environmental protection enterprises using a data envelopment analysis according to the existing literature on the measurement of financing efficiency of energy-saving and environmental protection enterprises [48,50]. Based on the principles of applicability, accessibility, and the importance of the indicators, four categories of indicator variables that measure the way companies finance themselves were selected as input indicators. The first is endogenous financing, which consists mainly of surplus and undistributed profits [57,58]. The second is debt financing. Debt financing mainly refers to non-current liabilities [59,60]. The third is equity financing. Equity financing mainly includes paid-in capital and capital surplus [61]. The fourth is fiscal financing. Fiscal financing mainly refers to government subsidies [62].

The output indicators for energy-saving and environmental protection enterprises were selected to reflect three aspects of the enterprise's operating capacity, profitability, and technological innovation: (1) main business revenue [58,63], (2) net profit [64,65], and (3) intangible assets [66].

The specific indicators are shown in Table 1.

Table 1. Evaluation index of inputs and outputs of financing efficiency.

Type of Indicator	Tier 1 Indicators	Secondary Indicators	Indicator Description
Input indicators	Endogenous financing	Surplus reserves	Reflects the accumulated capital of a business drawn from its profit after tax.
		Unallocated profit	To provide security for the future capital needs of the business.
	Debt financing	Non-current liabilities	All debts of one year or more that are used in return for payment and are required to be repaid on a regular basis.
	Equity financing	Paid-in capital	The capital contributed by an investor to an energy-saving and environmental protection enterprise after it has been effectively controlled by the enterprise.
		Capital surplus	The amount of capital invested by investors in energy-saving and environmental protection enterprises exceeds the legal registered capital.
	Financial financing	Government grants	Reflects the level of financial support provided by the government for energy-saving and environmental protection enterprises.
Output indicators	Operating income	Revenue from main business	Reflects the stage of growth of energy-saving and environmental protection companies and determines their growth capability.
	Operating profit	Net profit	It reflects the profitability, solvency, and management level of energy-saving and environmental protection enterprises.
	Corporate assets	Intangible assets	It reflects the technological innovation capability of energy-saving and environmental protection enterprises and can measure the potential of enterprises to gain future economic benefits and financing.

3.2.2. Dimensionless Data Processing

The DEA model can only identify non-negative inputs and output indicator values during the calculation process [61]. However, during the actual selection of data, it was found that some of the indicator values were negative. Therefore, in order to ensure that the study can be calculated using the DEA model, the negative data in the financing efficiency input and output indicators need to be dimensionless. One of the most used methods is the dimensionless data processing method. Dimensionless data are guaranteed to be positive and do not affect the results of the study. The specific method is as follows:

$$X_{ij}{}^{*} = 0.1 + 0.9 \times \frac{X_{ij} - \min_i(X_{ij})}{\max_i(X_{ij}) - \min_i(X_{ij})} \quad (5)$$

X_{ij} is the raw value of the jth indicator for the i-th enterprise; $\min_i(X_{ij})$ and $\max_i(X_{ij})$ are the maximum and minimum values of the raw data for the jth indicator in the i-th enterprise, respectively; and $X_{ij}*$ is the calculated dimensionless value of the jth indicator for the i-th enterprise.

3.2.3. Selection of Factors Influencing the Efficiency of Financing

The financing efficiency of energy-saving and environmental protection enterprises refers to the ability of enterprises to obtain funds at a lower cost through their own means, technology, and other advantages, while adjusting their financing structure and making efficient use of the incorporated funds. At present, energy-saving and environmental protection enterprises are facing the dilemma of malicious low-price competition brought about by the homogenization of products and services. They need to take the responsibility of satisfying customers' demands for green development and build core competitiveness through technological progress to escape this dilemma and achieve high-quality development. Technological progress is manifested in the digital transformation of energy-saving and environmental protection enterprises; changes to traditional manufacturing and innovation processes; achieving process re-engineering with energy conservation and emission reductions in accordance with customers' demands; and the digital transformation of design, production, and marketing, thus providing customers with green products, green equipment, and green services, and playing a key role in productivity improvement through the use of new-generation information technology and green technological progress. The application of new-generation information technology such as big data, cloud computing, and blockchain is also changing the scale of energy-saving and environmental protection enterprises, building green ecosystems, bringing into play the scale effect. This will be a key launch pad for the future development of energy-saving and environmental protection enterprises and an important guarantee for their future financing efficiency.

The current selection of factors influencing the financing efficiency of the energy efficiency and environmental protection industry lacks factors based on the internal factors of energy efficiency and environmental protection companies, especially the digital transformation and green innovation issues that energy efficiency and environmental protection companies urgently face today. To this end, we built a comprehensive analytical framework based on the mechanisms of the factors influencing the financing efficiency of energy-saving and environmental protection enterprises according to four dimensions: scale factors, technology factors, structural factors, and efficiency factors, using a micro-enterprise content perspective in order to explore the main factors affecting the financing efficiency of energy-saving and environmental protection enterprises. A total of six factors affecting the financing efficiency of energy-saving and environmental protection enterprises, namely, enterprise size, digital transformation, green technology innovation, asset–liability ratio, profitability, and operational capacity, were selected in this study. The definition of each variable in Equation (4) is shown in Table 2.

Table 2. Variable definition table.

Variable Type	Variable Name	Variable Symbols	Variable Definitions
Explained variables	Financing efficiency	FE	Pure technical efficiency index [67,68]
Explanatory variables	Business size	SIZE	Logarithm of total assets
	Digital transformation	DLTN	The text content of the annual reports of enterprises was extracted by IntelliJ IDEA, matched with word frequencies related to digital transformation, and the word frequencies were summed to obtain logarithms as proxy variables for digital transformation. The selection of keywords was based on Wu Fei's study [61]
	Green technology innovation	INNO	(Closing intangible assets-Opening intangible assets)/Total assets at the end of the period [69]
	Gearing ratio	DA	Total liabilities/total assets
	Profitability	ROA	Total net asset margin
	Operating capacity	CAT	Current asset turnover ratio

(1) Digital transformation

Digitization is a new production resource and production factor that helps companies to store data, analyze them, and utilize them. The use of digital technology can help enterprises to build a digital platform for their business and effectively reduce information asymmetry through the interconnection of multiple systems. The essence of digital transformation is to enhance the flow of data through digital technology, resolve system instability, and optimize resource allocation efficiency. According to resource allocation theory, the optimization of resource allocation can improve the efficiency of enterprise production and operation and reduce the cost of enterprise financing [70–72]. Zhuang and Wang (2022) argue that digital transformation can effectively reduce the information asymmetry effect among enterprises and improve financing efficiency [73].

(2) Green technology innovation

As the main force in energy-saving and emission reduction strategies, as well as in improving the ecological environment, green technology innovation is an inevitable choice for energy-saving and environmental protection enterprises to help achieve carbon peaks and carbon neutrality. As energy-saving and environmental protection enterprises' green technology innovation is often reflected in the positive externalities of their products on environmental benefits, in the context of carbon peaking and carbon neutrality, green, environmentally friendly products can effectively cater to consumers' needs, increase the economic benefits of enterprises, and help improve the efficiency of their financing [74]. In the context of carbon peaking and carbon neutrality, green and environmentally friendly products can effectively meet consumers' needs, increase the economic benefits of enterprises, and help improve the efficiency of corporate financing. Therefore, this paper innovatively explores the impact of green technology innovation on the financing efficiency of energy-saving and environmental protection enterprises.

(3) Size of the business

The impact of firm size on financing efficiency has been confirmed in previous studies, but the direction of the impact of firm size on financing efficiency can vary across firms; for example, Pan et al. found that the firm size of environmental firms had a positive impact on financing efficiency [51], while Du et al. found that the firm size of port firms had a negative impact on financing efficiency [75]. Based on signaling theory, this paper argues that larger enterprises have stronger economic strength, better management systems, and stronger decision-making capabilities than smaller enterprises, and can convey more information about good business conditions and have more opportunities to obtain financing from financial institutions or individual investors.

(4) Gearing ratio

The gearing ratio is an important indicator of the level of debt financing and the degree of risk of a company. Scholars have not yet reached a consensus on the impact of gearing on financing efficiency. Zeng et al. found that the lower the gearing ratio of strategic emerging industries, the higher their financing efficiency [44]. Tong et al. [76] found that, the higher the gearing ratio, the higher the financing efficiency. Combined with the current financing situation of energy-saving and environmental protection enterprises, this paper argues that the higher the gearing ratio of energy-saving and environmental protection enterprises, the lower the financing efficiency.

(5) Profitability

Scholars' studies have confirmed the positive impact of profitability on financing efficiency. For example, Liu et al. found a positive correlation between profitability and the financing efficiency of AI firms [77]. Xie et al. found that among western energy conservation and environmental protection firms, the more profitable the firms, the more efficient their financing [50]. Thus, the higher the profitability, the higher the financing efficiency.

(6) Operating capacity

Firms with strong operational capacity can send positive messages to the market and attract more investors to their investment decisions. Wang et al. suggest that technology-based firms with stronger operational capabilities are more efficient in raising capital [46]. The study by Huang et al. found that logistics companies with strong operational capacity significantly increase their financing efficiency [78].

3.2.4. Model Construction

Based on the previous results on the financing efficiency of energy-saving and environmental protection enterprises and the mechanism of the influencing factors, a model of the influencing factors on the financing efficiency of energy-saving and environmental protection enterprises was constructed. Since the explanatory variable financing efficiency index is between 0 and 1, which is a restricted variable, the regression of the model using the least squares method will lead to biased results [79]. Therefore, the Tobit model was chosen for regression testing. The regression analysis was carried out using the Tobit model with pure technical efficiency as the explanatory variable and each influencing factor as the explanatory variable. The multiple linear regression model constructed is shown in Equation (6):

$$FE = \beta_0 + \beta_1 SIZE + \beta_2 DLTN + \beta_3 INNO + \beta_4 DA + \beta_5 ROA + \beta_6 CAT + \varepsilon_{it} \quad (6)$$

3.3. Data Sources

We selected environmental protection concept stocks listed in 2015–2020 as the sample and, after excluding the enterprises with abnormal financial status and partially missing data, a total of 205 energy-saving and environmental protection enterprises were obtained as the research objects. Based on input and output variables, the DEAP 2.1 software was used to conduct static and dynamic analyses of the financing efficiency levels of 205 energy-saving and environmental protection sample enterprises in China from 2015 to 2020. The raw data were obtained from the CASMAR database.

4. Results and Discussion

4.1. Results

4.1.1. Criteria for Grading the Efficiency of Financing

In the summary analysis of the financing efficiency measurement results, reference was made to the study by Wu and Zeng [37] (2019) on efficiency classes; the individual efficiency values measured by the DEA model were classified into four classes, i.e., inefficient, less efficient, higher efficiency, and optimum efficiency. The classification criteria are shown in Table 3.

Table 3. Standard table of efficiency grade classification.

Distribution of Efficiency Intervals	**0 < H < 0.5**	**0.5 ≤ H < 0.8**	**0.8 ≤ H < 1**	**H = 1**
Efficiency levels	Inefficient	Less efficient	Higher efficiency	Optimum efficiency

4.1.2. Analysis of Financing Methods

Endogenous financing, debt financing, equity financing, and fiscal financing were selected as the input indicators to measure the financing efficiency of energy-saving and environmental protection enterprises based on their financing methods for 2015–2020; the financing structure is shown in Figure 1 according to the static analysis of the financing efficiency of energy-saving and environmental protection enterprises.

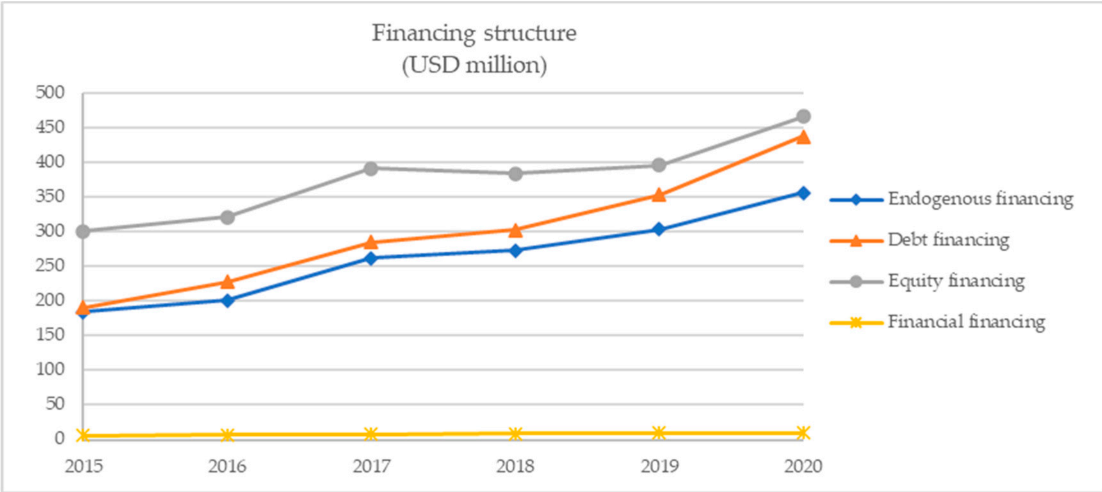

Figure 1. Financing structure of energy-saving and environmental protection enterprises.

An analysis of Figure 1 shows that from 2015 to 2020, equity financing was the main source of financing for listed companies in the energy-saving and environmental protection industry, followed by debt financing, endogenous financing, and fiscal financing. In 2017, equity financing, debt financing, and endogenous financing rose slightly, probably due to the expansion of production scale by energy-saving and environmental protection enterprises after the 13th Five-Year Plan, which required a large increase in capital.

4.1.3. Comprehensive Analysis of Static Financing Efficiency

We used the DEAP 2.1 software (Armidale, Australia) to measure the financing efficiency of 205 energy-saving and environmental protection enterprises from 2015 to 2020 from a static perspective; the results are shown in Table 4.

As can be seen from Table 4, the number of companies with the best overall technical efficiency fluctuated between 2015 and 2020, with an overall downward trend. The number of enterprises in the best efficiency range and the lower efficiency range decreased; the number of enterprises in the higher efficiency range increased; and the number of enterprises in the lower efficiency range did not change significantly. The main reasons for this trend are two-fold: Firstly, as energy-saving and environmental protection enterprises have been growing at a rapid pace in recent years, the management capabilities of most energy-saving and environmental protection enterprises have lagged their expansion rate, resulting in poor capital allocation and inefficient financing. Secondly, because energy-saving and environmental protection enterprises are technology intensive, the limited capital invested in technology research and development results in a much smaller output than the input, making financing inefficient. In terms of the mean value of comprehensive technical efficiency, the mean value of the comprehensive technical efficiency of energy-saving and environmental protection enterprises during 2015–2020 showed a decreasing–rising–decreasing trend, with values less than one, implying that the financing efficiency of energy-saving and environmental protection enterprises in China varied considerably during the study period, with poor efficiency and an overall non-efficient state.

In terms of pure technical efficiency (see Table 4), the pure technical efficiency in each range between 2015 and 2020 was relatively stable with small changes. Most energy-saving and environmental protection enterprises were in the higher efficiency range, with the number of enterprises in the best efficiency range still in the minority. The main reason for this trend is that, with the strong support of national policies, energy-saving and environmental protection enterprises are expanding their financing, but the lack of a scientific management system and differing management levels makes it difficult to reach the optimal level of pure technical efficiency. In terms of the average value of pure technical efficiency, the average value of all years was less than 1, which is not the best efficiency status, and optimal efficiency remains to be achieved, which needs to be improved by improving the technology and management levels.

Table 4. Static analysis results of financing efficiency of energy-saving and environmental protection enterprises from 2015 to 2020.

	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Comprehensive Technical Efficiency						
Best efficiency as a percentage (%)	23.41	19.02	5.85	17.56	17.07	12.2
Higher efficiency as a percentage (%)	72.68	76.59	12.68	74.63	78.05	80.98
Percentage of lower efficiency (%)	3.41	3.09	80.49	7.8	4.88	6.34
Percentage of inefficiencies (%)	0.49	0.49	0.98	0	0	0.49
Average value	0.95	0.941	0.75	0.928	0.936	0.917
Pure Technical Efficiency						
Best efficiency as a percentage (%)	40	39.51	37.56	40.98	43.41	38.54
Higher efficiency as a percentage (%)	57.07	58.05	59.51	55.61	55.61	59.51
Percentage of lower efficiency (%)	2.44	1.95	2.93	3.41	0.98	1.95
Percentage of inefficiencies (%)	0.49	0.49	0	0	0	0
Average value	0.968	0.969	0.969	0.966	0.971	0.965
Scale Efficiency						
Best efficiency as a percentage (%)	5.47	7.46	6.47	9.45	5.97	8.46
Higher efficiency as a percentage (%)	70.73	77.56	21.95	76.1	80	81.95
Percentage of lower efficiency (%)	0	0.98	72.2	2.44	2.44	3.9
Percentage of inefficiencies (%)	0	0	0	0	0	0
Average value	0.98	0.97	0.775	0.96	0.963	0.949

Regarding scale efficiency (see Table 4), in terms of the number of enterprises at different efficiency levels each year, the number of enterprises whose scale efficiency is in the best efficiency range varied considerably between 2015 and 2020, with an overall downward trend. The main reason for this trend is that energy-saving and environmental protection enterprises blindly expand their energy-saving and environmental protection products to meet market demand, neglecting the optimal allocation of inputs and outputs. In terms of the mean value of scale efficiency, it was at [0.775,0.980], with a large trend of change.

Overall, the overall technical efficiency of energy-saving and environmental protection enterprises fluctuated between 0.750 and 0.950 during the period 2015–2020. Since the comprehensive technical efficiency was equal to the product of pure technical efficiency and scale efficiency, when the comprehensive technical efficiency was decomposed, the average value of pure technical efficiency was found to be stable at around 0.960, while the average value of scale efficiency was at [0.775,0.980], and the trend of change in scale efficiency was found to be more consistent with the trend of change in comprehensive technical efficiency, indicating that the comprehensive technical efficiency of energy-saving and environmental protection enterprises is more influenced by the change in scale efficiency.

4.1.4. Comprehensive Analysis of Dynamical Financing Efficiency

As the traditional DEA static model can only measure the efficiency of financing at each point in time, to make up for the shortcomings of the static analysis, we used DEAP 2.1 software to measure the Malmquist index of the sample energy-saving and environmental protection enterprises from 2015 to 2020. After collation, the results of the Malmquist index analysis for the sample energy-saving and environmental protection enterprises are shown in Table 5.

Table 5. Malmquist index of energy conservation and environmental protection enterprises.

Periods	Comprehensive Technical Efficiency Change Index	Technological Advances Index	Pure Technical Efficiency Change Index	Scale Efficiency Index	Malmquist Index
2015–2016	0.991	0.827	1.002	0.989	0.820
2016–2017	0.795	0.812	1.000	0.795	0.645
2017–2018	1.241	1.230	0.997	1.244	1.526
2018–2019	1.010	0.813	1.006	1.004	0.821
2019–2020	0.978	1.048	0.993	0.985	1.025
Mean	0.993	0.932	1.000	0.993	0.926

Overall, the Malmquist index for energy-saving and environmental protection enterprises showed a W shape over the period 2015–2020. In terms of the geometric mean, the Malmquist index had a mean value of 0.926, indicating that the financing efficiency of Chinese energy-saving and environmental protection enterprises decreased by 7.4% between 2015 and 2020, with the technological progress index showing a negative growth of 6.8%, and the average growth rate of the comprehensive technical efficiency change index was 0.7% negative. The impact of the decline in the technological progress index of environmental protection enterprises is manifested in a decline in overall financing efficiency. By splitting the composite technical efficiency change index into a pure technical efficiency change index and a scale efficiency index, it was mainly the scale efficiency index that showed a negative growth rate of 7%, which had a negative impact on the financing efficiency of the sample companies.

From the measured results, technical regression and low scale efficiency are the reasons why financing efficiency is in a non-efficient state. The improvement in the financing efficiency of energy-saving and environmental protection enterprises requires a combination of technological progress and the impact of scale efficiency. Technological progress mainly refers to the green technology innovation and digital transformation of energy-saving and environmental protection enterprises, which manifests itself in the output of green technologies and services, as well as the digital transformation of design, production, and marketing. This will be a key driving force for the future development of energy-saving and environmental protection enterprises, as well as an important guarantee for their future financing efficiency improvement.

4.2. Discussion

4.2.1. Different Ways of Analyzing Static Financing Efficiency

Based on the DEA model, the financing efficiency of the different financing methods analyzed are shown in Table 6:

(1) An analysis of Table 5 and Figure 2 shows that the average total financing efficiency of the four financing methods varied widely, with the combined efficiency of endogenous financing and equity financing being greater at 0.81 and 0.733, respectively, and maintaining a combined efficiency value above 0.7 in most years. The combined technical effect of debt financing and fiscal financing was relatively low, at 0.358 and 0.366, respectively. The reason for this may be that debt financing and fiscal financing have more demanding and stringent conditions, making it difficult to meet the demand for the financing scale for the digital transformation and green technology innovation of energy-saving and environmental protection enterprises. Reliance on debt and government financial support makes it difficult to adequately cover the funds needed for the high-quality development of energy-saving and environmental protection enterprises.

Table 6. Efficiency of different financing methods.

Year	Endogenous Financing			Debt Financing			Equity Financing			Fiscal Financing		
	Crste	Vrste	Scale	Crste	Vrste	Scale	Crste	Vrste	Scale	Crste	Vrste	Scale
2015	0.897	0.935	0.958	0.31	0.928	0.341	0.789	0.904	0.872	0.363	0.918	0.401
2016	0.833	0.92	0.904	0.397	0.93	0.433	0.75	0.897	0.834	0.399	0.928	0.432
2017	0.641	0.925	0.699	0.366	0.909	0.413	0.542	0.9	0.606	0.359	0.928	0.393
2018	0.849	0.93	0.913	0.379	0.911	0.426	0.783	0.908	0.861	0.343	0.918	0.378
2019	0.86	0.934	0.921	0.351	0.91	0.399	0.779	0.917	0.85	0.359	0.907	0.404
2020	0.782	0.929	0.843	0.345	0.905	0.396	0.754	0.924	0.817	0.375	0.916	0.414
Average	0.81	0.929	0.873	0.358	0.916	0.401	0.733	0.908	0.807	0.366	0.919	0.404

Note: Crste represents comprehensive technical efficiency; Vrste represents pure technical efficiency; Scale represents scale efficiency.

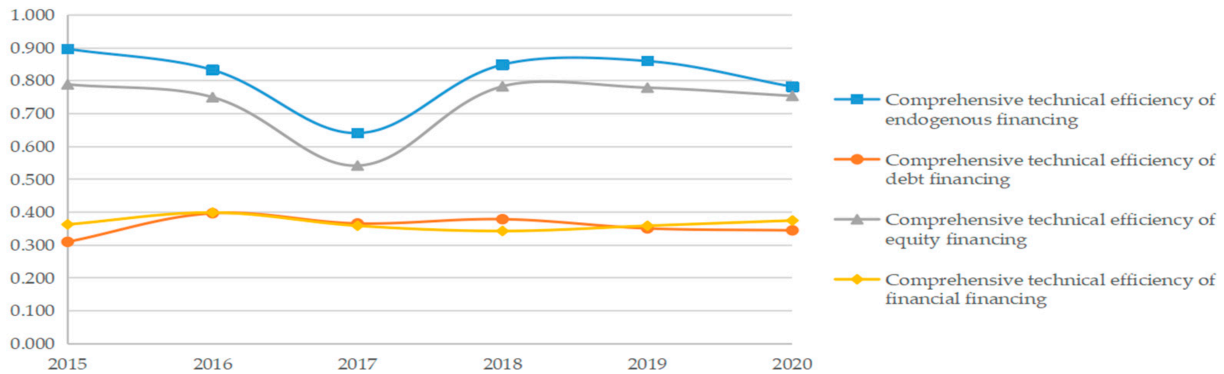

Figure 2. Comprehensive technical efficiency of different financing methods.

(2) An analysis of Table 5 and Figure 3 shows that endogenous financing had the highest efficiency of pure technical financing, with an average of 0.929 and a value greater than 0.9 for each year. Equity financing had the second highest efficiency of pure technical financing, with a value of 0.908, but there is still room for improvement.

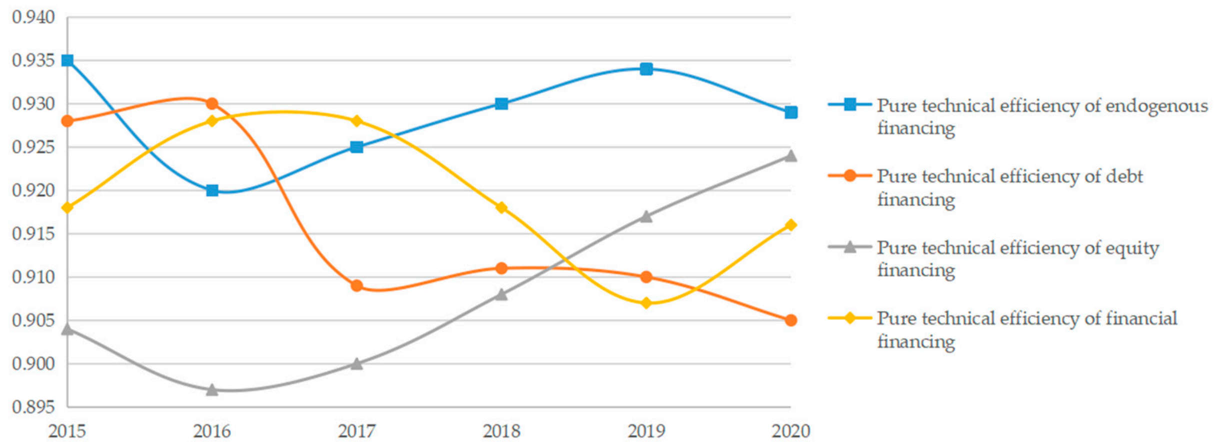

Figure 3. Pure technical efficiency of different financing methods.

(3) An analysis of Table 5 and Figure 4 shows that endogenous financing and equity financing were more efficient in scale, both being greater than 0.8, while debt financing and financial financing were lower. This is related to the characteristics of energy-saving and environmental protection enterprises, which have large initial investments in digital transformation and green technology innovation, uncertainty, and long lead times in generating returns, and are overlaid with information asymmetry. For this reason, energy-saving and environmental protection enterprises need to seek the optimal scale of production in order to improve the efficiency of financing.

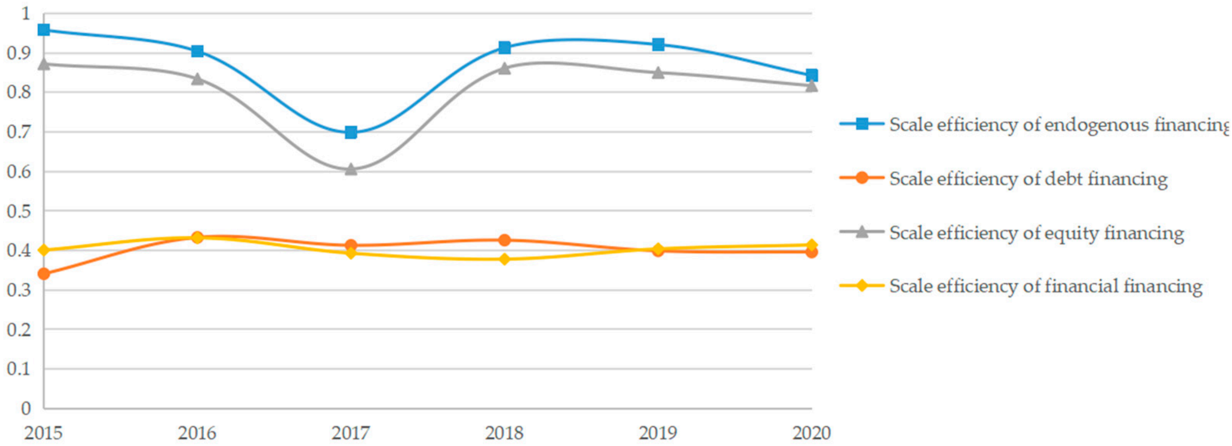

Figure 4. Scale efficiency of different financing methods.

In summary, the change in the level of the combined technology effect depends largely on the scale effect of the energy-saving and environmental protection industry. The trends of change in the two were similar. This suggests that the financing efficiency brought about by technological progress is offset by the scale effect. Both endogenous financing and equity financing declined significantly in 2017, which may be attributed to the start of the implementation of the 13th Five-Year Plan in 2017. In this context, energy-saving and environmental protection enterprises are rapidly expanding, but they have difficulty in achieving the expected financing efficiency due to technological innovation and internal management levels that have not yet been improved.

4.2.2. Different Ways of Analyzing Dynamical Financing Efficiency

Based on the Malmquist model, and considering comprehensive technical financing efficiency and the technological advances index, different financing methods were analyzed, and the results are as follows:

From Tables 7–10, we can conclude that:

1. The four types of financing, i.e., equity financing, endogenous financing, financial financing, and debt financing, have annual average Malmquist indices of 0.916, 0.923, 1.020 and 1.025, respectively.
2. The Malmquist index of equity financing declined by an average of 8.4%, and in further analysis, the comprehensive technical efficiency change index declined by 0.9% and the technological change advances index, on average, declined by 7.5% in further analysis. Technological regression has led to a decline in equity financing.

The Malmquist index of endogenous financing fell by an average of 7.7% and, upon further analysis, the comprehensive technical efficiency change index fell by 2.8% and the technological change advances index fell by 5.1%, upon further analysis. The scale efficiency index fell by 2.7% and it can be concluded that the main reason for the decline in the efficiency of endogenous financing was due to technological regression.

Table 7. Malmquist index of endogenous financing.

Periods	Comprehensive Technical Efficiency Change Index	Technological Advances Index	Pure Technical Efficiency Change Index	Scale Efficiency Index	Malmquist Index
2015–2016	0.926	0.834	0.982	0.942	0.772
2016–2017	0.771	0.75	1.005	0.767	0.578
2017–2018	1.323	1.352	1.007	1.314	1.789
2018–2019	1.017	0.784	1.006	1.011	0.797
2019–2020	0.904	1.164	0.993	0.911	1.053
mean	0.972	0.949	0.999	0.973	0.923

Table 8. Malmquist index of equity financing.

Periods	Comprehensive Technical Efficiency Change Index	Technological Advances Index	Pure Technical Efficiency Change Index	Scale Efficiency Index	Malmquist Index
2015–2016	0.948	0.789	0.991	0.957	0.748
2016–2017	0.722	0.834	1.006	0.718	0.603
2017–2018	1.442	1.152	1.008	1.430	1.660
2018–2019	1.005	0.847	1.013	0.992	0.851
2019–2020	0.961	1.056	1.007	0.954	1.015
mean	0.990	0.925	1.005	0.986	0.916

Table 9. Malmquist index of debt financing.

Periods	Comprehensive Technical Efficiency Change Index	Technological Advances Index	Pure Technical Efficiency Change Index	Scale Efficiency Index	Malmquist Index
2015–2016	1.291	0.843	1.004	1.285	1.088
2016–2017	0.931	1.395	0.973	0.957	1.299
2017–2018	1.021	0.758	1.000	1.020	0.774
2018–2019	0.955	1.081	1.000	0.955	1.032
2019-2020	0.950	1.055	0.989	0.960	1.002
mean	1.022	1.003	0.993	1.028	1.025

Table 10. Malmquist index of fiscal financing.

Periods	Comprehensive Technical Efficiency Change Index	Technological Advances Index	Pure Technical Efficiency Change Index	Scale efficiency Index	Malmquist Index
2015–2016	1.106	0.960	1.016	1.088	1.061
2016–2017	0.910	1.646	0.999	0.911	1.498
2017–2018	0.938	0.694	0.989	0.948	0.651
2018–2019	1.059	1.024	0.985	1.075	1.084
2019–2020	1.039	0.948	1.012	1.027	0.985
mean	1.008	1.012	1.000	1.007	1.020

The Malmquist index of debt financing rose by an average of 2.5% and, on further analysis, the comprehensive technical efficiency change index rose by 2.2%, with the scale efficiency index rising by 2.8%. This shows that scale efficiency is the key reason for the increase in debt financing.

The Malmquist index of debt financing rose by an average of 2%. Further analysis shows that the index of change in the technological change advances index rose by 1.2% and the comprehensive technical efficiency change index rose by 0.8%. This shows that technological progress is the key reason for the increase in fiscal financing.

To sum up, the two main reasons for the inefficient financing of China's energy efficiency and environmental protection industry in 2015–2020 were the improvements in the scale efficiency and technological advancement.

3. The main reasons for the fluctuations from 2015 to 2020, in terms of changes in the Malmquist index are follows. Firstly, the energy conservation and environmental protection industry needs to build a long-term core model for competitiveness. The advancing level of technology, the accumulation of management experience, and the strength of policy support and enforcement are key issues that constrain the high-quality development of energy-saving and environmental protection enterprises. Secondly, under the guidance of policies, capital is pouring into the energy-saving and environmental protection industry, but the industry's economic efficiency is low and profitability levels continue to decline, leading to under-performance in financing

efficiency. This is also where the difficulty of financing and the low efficiency of financing comes in.

4. The Malmquist index fell by 34.5% in 2016–2017, while it rose by 52.6% in 2017–2018. This may be because the energy conservation and environmental protection industry is relatively more subjected to the influence of environmental protection policies. A series of supportive policies were released in 2016 to promote the great development of environmental protection; since 2016–2017, debt financing and equity financing have risen sharply, bringing about the expansion of enterprise scales, due to the large scale of initial investment in the environmental protection industry and the relatively long investment cycle. As a result, the expansion of industry scale has in turn brought about a reduction in financing efficiency and operational efficiency. In 2017–2018, the change in financing scale levelled off, with technology and scale factors coming into play.

4.2.3. Analysis of the Influencing Factors of Financing Efficiency

As the data used in this paper were short panel data, there are two main forms of mature panel Tobit models according to Cheng and Long (2017): the mixed effects Tobit model and the random effects Tobit model [80]. The specific model to be used can be selected by the LR test results [81]. In this paper, based on the above study, the LR test was conducted on the panel data before regression. After the test, the LR result was 0.000, leading to the rejection of the original hypothesis of the mixed effects model, so we chose the random effects Tobit model. The regression results are shown in Table 11.

Table 11. Tobit regression results of financing efficiency.

Explanatory Variables	Coefficient	Std. Err.	t	$p > \|t\|$
SIZE	−0.0408998 ***	0.0031479	−12.99	0.000
DLTN	0.004056 *	0.0021897	1.85	0.064
INNO	0.3867846 ***	0.1032167	3.75	0.000
DA	0.0387421 *	0.0222210	1.74	0.082
ROA	0.1032485 *	0.0566296	1.82	0.069
CAT	0.035325 ***	0.0054728	6.45	0.000

Note: t-statistics in parentheses. *** $p < 0.01$, * $p < 0.1$.

As can be seen from the regression results in Table 6, firm size, digital transformation, green technology innovation, gearing, profitability, and operating capacity all affect the efficiency of financing for energy-saving and environmental protection firms.

At the scale factor level, the size of the energy-saving and environmental protection enterprises is negatively related to their financing efficiency, which is consistent with the findings of Xie et al. [50], suggesting that the larger the size of the energy-saving and environmental protection enterprises, the lower their financing efficiency. Although larger enterprises have more financing advantages and wider financing channels, due to the high investments and long cycles of energy-saving and environmental protection enterprises, too large a scale will lead to slower capital recovery. When the operation mode and management system of the enterprise cannot keep up with the expansion rate of the enterprise, this will significantly increase the financing cost of the enterprise, which is not conducive to the improvement of financing efficiency.

At the level of technical factors, the digital transformation of energy-saving and environmental protection enterprises is positively related to financing efficiency, indicating that the digital transformation of energy-saving and environmental protection enterprises positively affects financing efficiency. Digital transformation can enhance data flow, optimize resource allocation efficiency, reduce information asymmetry, and enable effective improvement in financing efficiency. There is a positive relationship between green technology innovation and financing efficiency, indicating that the stronger the degree of green technology innovation of energy-saving and environmental protection enterprises, the higher their financing efficiency. Energy-saving and environmental protection enterprises are the main force behind green development, and carrying out green technological innovation can not only bring about technological progress, but can also increase operational efficiency [82]. This helps to improve financing efficiency.

At the level of structural factors, the asset–liability ratio of energy-saving and environmental protection enterprises is positively related to their financing efficiency. This indicates that a higher gearing ratio of energy-saving and environmental protection enterprises will increase their financing efficiency. This is mainly because energy-saving and environmental protection enterprises currently have a low gearing ratio with a good tax shield effect, and an increase in gearing within a certain range will help to improve their financing efficiency.

At the level of efficiency factors, the profitability of energy-saving and environmental protection enterprises is positively related to their financing efficiency. This indicates that the more profitable an energy efficiency company, the more efficient its financing. The higher the profitability, the higher the revenue generated by the financing, and the more retained earnings can be accumulated for internal financing [83]. This can effectively improve financing efficiency. There is a positive relationship between operating capacity and financing efficiency, which is consistent with the original hypothesis, indicating that the stronger the operating capacity of energy-saving and environmental protection enterprises, the more they can contribute to the improvement of their financing efficiency. As emerging strategic industries, enterprises with a strong operating capacity have a fast turnover of assets and can obtain more revenue in a short period of time, thus effectively improving their financing efficiency.

5. Conclusions and Enlightenment

5.1. Conclusions

We empirically analyzed the financing efficiency of 205 energy-saving and environmental protection enterprises from 2015 to 2020 by introducing DEA and the Malmquist index, and used the Tobit model to analyze the influencing factors of financing efficiency. We obtained the following conclusions: (1) The financing efficiency of energy-saving and environmental protection enterprises is inefficient; the capital allocation rate is relatively low; and the financing efficiency of enterprises has room for future improvement. (2) In terms of financing methods, the overall efficiency and scale efficiency of endogenous financing and equity financing are high, and the pure technical efficiency shows a continuous upward trend. While the pure technical efficiency of debt financing continues to decline, the pure technical efficiency of financial financing fluctuates widely, and the overall trend shows a decline. (3) Digital transformation, green technology innovation, the asset–liability ratio, profitability, and operational capacity have a significant positive impact on the financing efficiency of energy-saving and environmental protection enterprises. (4) Enterprise size has a significant negative impact on the financing efficiency of energy-saving and environmental protection enterprises.

5.2. Suggestions

Energy-saving and environmental protection enterprises play an important role in promoting China's goal of achieving a dual carbon strategy. In view of the current problem of the low overall financing efficiency of energy-saving and environmental protection enterprises, the following suggestions are put forward to improve the efficiency of resource allocation and enhance the financing efficiency of energy-saving and environmental protection enterprises, considering the results of the research on the influencing factors. (1) Increase financing policy support: At present, energy-saving and environmental protection enterprises are in a period of digital transformation and green technological innovation, and the government needs to continue to increase its financing policy support to promote the improvement of enterprise financing efficiency and the achievement of carbon peaking and carbon neutrality goals. For example, financial subsidies should be provided to guide energy-saving and environmental protection enterprises to actively carry out digital transformation and green technology innovation activities. Tax incentives should be increased to ensure that tax support and tax subsidies are put into practice. (2) Improve diversified investment and financing mechanisms: Improving the diversified investment and financing mechanisms would encourage the active inflow of diversified funds to ensure the efficient operation of investment and financing activities of energy-saving and environmental protection enterprises. Banks should be encouraged to develop new financial instruments, innovate green credit businesses, and improve green channels for financing energy-saving and environmental protection enterprises. The top-level design of intangible asset financing policies should be strengthened, and intangible asset financing channels and risk-sharing mechanisms should be improved. Direct financing by combining equity and debt should be promoted, and capital markets should enhance the inclusiveness and universality of the financing system and give special financial support to energy-saving and environmental protection enterprises. (3) Accelerate the construction of digital transformation: Digital transformation is an important aspect in the enhancement of the business value of enterprises. In the process of digital transformation, energy-saving and environmental protection enterprises should pay attention to transforming traditional management thinking and creating an ecosystem of cross-disciplinary synergy. (4) Promote green technology innovation: The future development advantages of energy-saving and environmental protection enterprises lie in their ability to start each production and operation chain with green technological innovation and the establishment of a stable green technological innovation alliance to fully integrate information resources among enterprises and achieve information resource sharing to effectively solve a series of problems such as pollution prevention and control and resource recycling. (5) Reasonable adjustment of the scale of enterprise development: Energy-saving and environmental protection enterprises in their production and operation processes should consider the market needs regarding core comprehensive technological innovation, production capacity, and other factors to determine their development scale to achieve the optimal allocation of resources.

5.3. Deficiencies and Prospects

Although this paper provides insight into the factors influencing the financing efficiency of energy-saving and environmental protection enterprises, there are still some shortcomings that need to be explored in the future. Firstly, this paper focuses on listed environmental protection stocks, and although this provides data to test the model of the factors influencing financing efficiency, it is not yet known whether it can be used to study the factors influencing the financing efficiency of all energy-saving and environmental protection firms. Future research can further explore the study of financing efficiency and its influencing factors by selecting non-listed energy efficiency and environmental protection enterprises, thus enriching research results regarding financing efficiency in China's energy-saving and environmental protection industry. Secondly, by using the EDA model and the Malmquist index to measure the financing efficiency of the energy-saving and environmental protection industry, the choice of input and output indicators has a decisive influence on the results of the evaluation of the financing efficiency of the energy-saving and environmental protection industry. The choice of input and output indicators is somewhat subjective, and this may affect the results of the evaluation of the financing efficiency of the energy-saving and environmental protection industry. In future research, better indicators can be selected to reflect the financing efficiency of the energy-saving and environmental protection industry based on the rooting theory. Thirdly, when applying the Tobit model for regression, we selected digital transformation, green technology innovation, gearing, profitability, operating capacity, and firm size as the key factors affecting the financing efficiency of energy-saving environmental protection firms, and this thus explains the impact of the dual carbon policy and digital transformation on the financing efficiency of environmental protection firms, but we did not consider the impact of financing costs and financing risks. Future research could further explore the mechanisms of financing costs and financing risk in relation to financing efficiency.

In the future, as people's awareness of environmental protection increases and the energy-saving and environmental protection industry continues to grow and develop, related research will become more abundant. We will continue to track the development and financing of energy-saving and environmental protection enterprises at home and abroad, as well as changes in national macro policies, and make recommendations to improve and refine the financing efficiency of the energy-saving and environmental protection industry. In turn, this will enhance the value of the environment and help achieve the harmonious coexistence of people and nature.

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