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Energy Efficiency Evaluation Model Based on Malmquist Index

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Abstract: With the continuous increase of energy demand, the use of energy has caused many environmental problems, and the energy crisis has gradually attracted people's attention. By understanding energy efficiency, it provides good policy suggestions for improving my country's energy efficiency. The purpose of this paper is to use the Malmquist index model to analyze the energy efficiency evaluation model. In the experiment, the correlation matrix data of the original variables in the energy efficiency evaluation model, the standard values of the energy subsystem indicators over the years and the evaluation table of the energy subsystem evaluation results are analyzed and summary. The experimental results show that the correlation coefficients between the selected indicators are all less than 0.7, that is, the correlation between the indicators is weak, and there is no strong correlation indicator (repetitive indicator). Energy consumption structure, improve energy efficiency, and improve the energy efficiency evaluation system model.

1. Introduction

China is a big energy country and also a big energy consumer. Energy is an important source of production and life. Lack of energy leads to rising energy prices, making energy into a crisis [1]. At the same time, the waste generated in the process of using a large amount of energy has endangered the vital natural environment and has become an obstacle to the implementation of sustainable improvement in my country. In this case, improving energy efficiency has become the only way for China to eliminate the two major causes of energy shortage and environmental pollution.

With the improvement of energy efficiency, my country's energy production cannot meet the current energy demand, and there is a large gap in energy demand. Ventura C recently proposed that there is growing interest in photovoltaic/thermal solar energy systems, as these allow the

simultaneous generation of heat and electricity. The thermal and electrical performance of a PV/T module is coupled, so it is critical to monitor both efficiencies to determine the optimal operating point. In this context, the aim is to numerically and experimentally investigate the electrical energy performance of PV/T modules suitable for on-line monitoring and control purposes. His research presented a new method for evaluating the electrical efficiency of PV/T modules as a function of coolant temperature, solar radiation and solar incidence angle. The proposed method is based on the calculation of the cell temperature of the PV/T module, which in turn is a function of the coolant temperature and the specific characteristics of the PV/T module. The model proposed in the literature for evaluating the electrical efficiency of PV modules has been redrafted to make it applicable to PV/T modules [2]. Nkm A believes that the circular economy aims to achieve sustainable development by paying more attention to renewable energy and precise management of waste, ensure safe access to resources, and combat climate change and global warming. Environmental concerns arising from energy use and the lack of policies to monitor them pose challenges to sustainable development. A circular economy emphasizes economic development with the least adverse impact on the environment. In order to evaluate the environmental performance of decision-making units through data envelopment analysis, a set of general weight models was developed using the ideal point method. Therefore, the energy and environmental efficiency of OECD countries was analysed using the Malmquist Productivity Index for 2012-2015 [3].

This paper studies the theory of energy efficiency, energy efficiency evaluation research, and China's countermeasures to improve energy efficiency. The Malmquist index model is used to analyze the energy efficiency evaluation model, and the correlation matrix data of the original variables in the energy efficiency evaluation model, the standard values of energy subsystem indicators and the evaluation table of energy subsystem evaluation results over the years are analyzed and summarized. The results show that the correlation of the selected indicators is weak. The overall energy utilization efficiency of my country's energy system is on the rise. Therefore, we need to further adjust and optimize the energy consumption structure, increase the improvement of clean energy, improve energy efficiency, and improve the energy efficiency evaluation system model.

2. Research on Energy Efficiency Evaluation Model Based on Malmquist Index

2.1 Theory of Energy Efficiency

The interpretation of the concept of energy efficiency by the World Energy Council is: on the premise of providing the same quality and level of service, the amount of energy input is reduced by using appropriate methods [4]. "Energy efficiency" is a general term, and there is no single quantitative measure. Many indicators can be used to evaluate changes in energy efficiency, and different indicators have different application scenarios and their own problems. The researchers try to find a suitable energy efficiency index to achieve comparison between different countries, and believe that if the energy efficiency index wants to be recognized by more countries, various energy policies should be considered comprehensively, and two basic principles are defined in the research. Efficiency concept: 1) The concept of economic efficiency, in daily production or life, the same or less energy resources are used, and the emission of carbon dioxide is also reduced, in such a case, the enterprise produces more and better Commodities, people's usual level has also been improved accordingly; 2) The concept of technical and economic efficiency, through the improvement of scientific level, the improvement of organizational level and the improvement of daily behavior to reduce the consumption of certain specific energy [5].

2.2 Energy Efficiency Evaluation Research

With the increasingly prominent contradiction between energy supply and demand and the increasing concern about global warming and environmental pollution, the issue of energy efficiency has received more and more attention from the international community [6]. The huge role of energy efficiency improvement in alleviating the upward pressure on energy prices, addressing potential environmental risks and enhancing energy security has become a consensus among policy makers around the world. The focus of scholars at home and abroad is mainly on the measurement of energy efficiency and the influencing factors and mechanisms of energy efficiency [7].

(1) Definition of energy efficiency

The concept of energy efficiency was first proposed by foreign scholars, and later scholars gradually added environmental protection, economic and other indicators in the research process for evaluation [8]. Energy efficiency refers to the degree to which energy is effectively utilized. When the research objects of energy efficiency are different, the calculation methods of energy efficiency are generally different. Energy efficiency refers to the use of relatively less energy while maintaining the same service or efficient output [9-10]. The results obtained by using different definitions and indicators are often quite different, which makes it difficult to judge the current level of energy efficiency in the region. Therefore, this paper gives a clear distinction and definition of energy utilization efficiency in different disciplines from multiple perspectives.

The biggest difference between energy efficiency and energy conservation is that although they have the same ultimate goal of reducing energy input, they adopt different methods and mechanisms, which means that energy efficiency focuses on directly adjusting energy input under given output decision conditions. energy demand, while energy saving focuses on reducing energy input indirectly by reducing the number of outputs [11-12].

(2) Analysis of Influencing Factors of Energy Efficiency

The analysis of the influencing factors of energy efficiency is an important content in energy efficiency research, and it is also a domestic research hotspot. The early research on the factors affecting energy efficiency mainly used time series data to study the long-term and short-term factors affecting energy efficiency from the time dimension. With the deepening of the research, scholars have found that the research from the time dimension alone cannot fully explain the reasons for the changes in energy efficiency, especially the regional differences and changes in energy efficiency. A more comprehensive study is carried out under the framework of economic growth [13-14]. There are two main categories of energy efficiency factorization methods: one is the factorization method, and the other is the model-based measurement method. The so-called factor decomposition method is to decompose the increment of the analysis object into several parts by mathematical methods, and make them correspond to each influencing factor one by one. In order to further identify the influencing factors of energy efficiency, some scholars have begun to try to use measurement methods for deeper analysis [15-16]. Based on previous studies, it is concluded that the influencing factors of energy efficiency mainly include industrial structure factors, technological progress factors, economic system factors, energy price factors, external improvement factors, government behavior and ownership reform and other factors.

2.3 China's Countermeasures to Improve Energy Efficiency

First, China's energy improvement should give priority to technical issues. The establishment of a smart grid can capture the information on the supply side and the demand side in the market in a

timely manner, and effectively manage the demand side, so as to effectively allocate energy and reduce the "abandoned light rate" and "abandoned wind rate". In addition, with the help of Internet technology, various energy consumption terminals can be improved with "smart meters" as the prototype. On the one hand, it is conducive to the interoperability of market information. Second, increase the proportion of renewable energy consumption and optimize China's energy consumption structure [17].

Second, how should China's coal consumption reduce its proportion in the energy transition process, and what role should the coal industry play in the energy system? At present, China's main economic improvement area is located on the eastern coast, and the energy consumption area is also located here. The local improvement of nuclear energy and offshore wind power can solve the problem of energy shortage in the east more quickly and efficiently [18-19]. However, my country's renewable energy technology is still not mature enough, and it is necessary to provide sufficient policy support, scientific research funding and human resource investment for new energy technology innovation, strengthen international cooperation, and learn from and transform mature technologies. The experience of the country's incentive policies, subsidy policies, and network access pricing policies can be used for reference.

3. Investigation and Research on Energy Efficiency Evaluation Model Based on Malmquist Index

3.1 Sample Selection

This paper takes my country's indicator data from 2012 to 2022 as the analysis sample. The energy indicator data that can be directly obtained comes from the website of the National Bureau of Statistics, etc., and the data that needs to be calculated indirectly use standard algorithms, so the data sources are reliable and authoritative.

3.2 Malmquist Exponential Model

In the article on distance function research published by StenMalmquist, the Malmquist index is used to compare the differences in the consumption characteristics of multiple groups with the indifference curve of a consumer group as a reference set. The Malmquist indices of the evaluation object at the technical level of the period t and t+1 are:

$$M_t = \frac{D_t(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)} \quad (1)$$

$$M_{t+1} = \frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_{t+1}(X_t, Y_t)} \quad (2)$$

4. Analysis and Research of Energy Efficiency Evaluation Model Based on Malmquist Index

4.1 Analysis of Energy Efficiency Evaluation Model

The five selected energy system indicators are tested for correlation respectively, where A_{11} represents the proportion of terminal consumption of electricity, A_{12} represents the proportion of coal consumed by terminal, and A_{13} is the growth rate of total energy consumption. The

correlation matrix of its original variables is shown in Table 1 and Figure 1 below:

Table 1. Energy subsystem index correlation coefficient matrix correlation coefficient

Correlation coefficent	A_{11}	A_{12}	A_{13}
A_{11}	1.5474	0.6879	0.4674
A_{12}	0.6487	1.2462	0.3978
A_{13}	0.4578	0.3548	1.1245

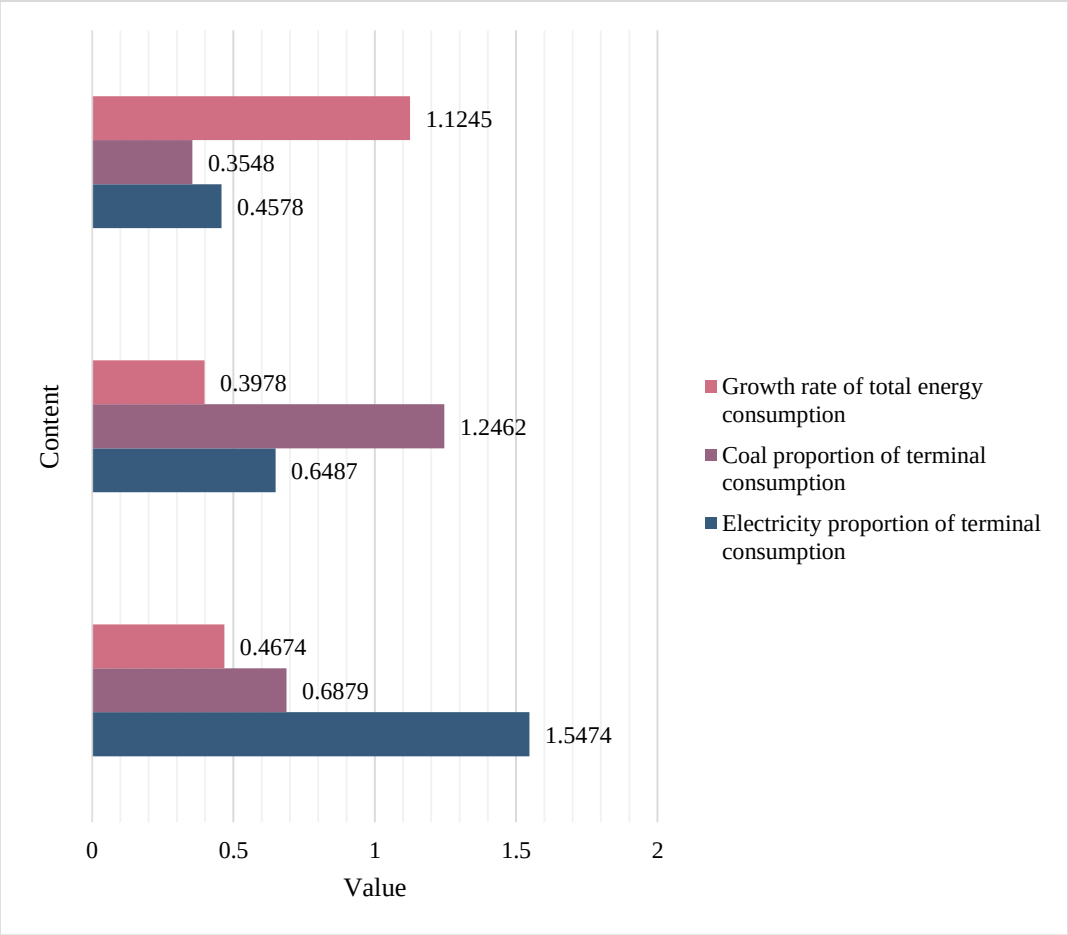

Figure 1. Comparison of correlation coefficient

The results show that the correlation coefficients between the selected indicators are all less than 0.7, that is, the correlation between the indicators is weak, there is no strong correlation index (repeated indicators), and it has good independence.

4.2 .Energy Subsystem Indicators

The original data were converged and standardized, and the standard values of the energy subsystem indicators and the evaluation results of the energy subsystem over the years were obtained as shown in Table 2, Figure 2 and Table 3:

Table 2. Standardized value of energy subsystem index

Code	2018	2019	2020
A_{11}	1.5848	1.8467	2.3654
A_{12}	1.4525	1.7869	2.3947
A_{13}	1.5474	1.8659	2.4547

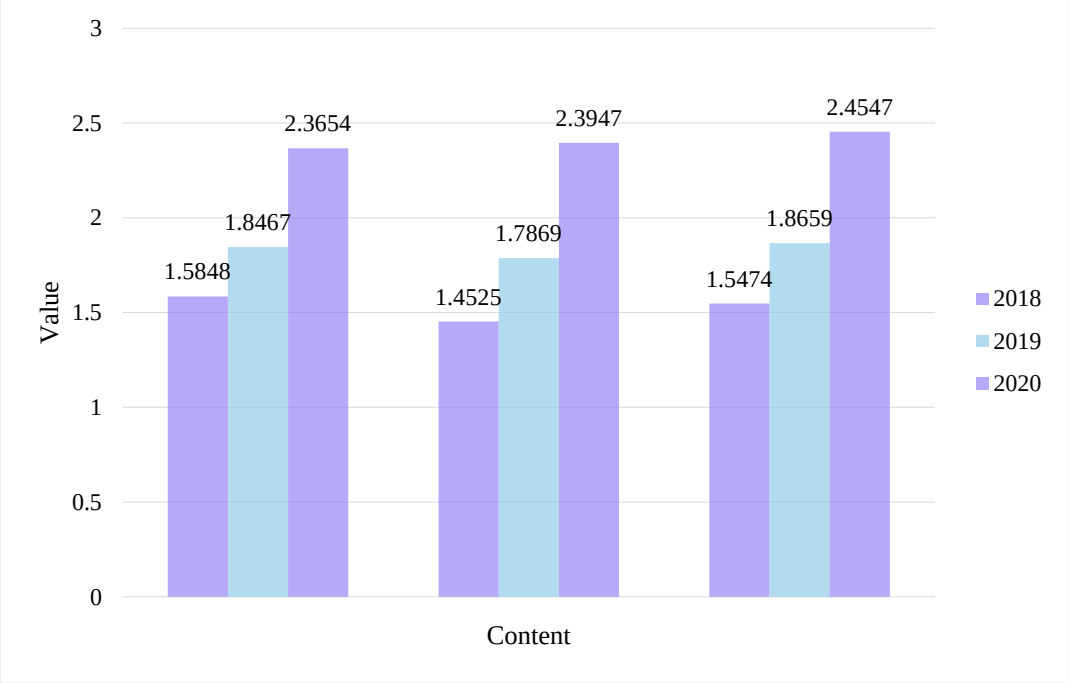

Figure 2. Comparison diagram of standardized values of energy system indicators

Results The overall energy utilization efficiency of my country's energy system showed an upward trend, and in recent years, the rising speed of the energy subsystem index has slowed down. This has a certain relationship with my country's current energy consumption structure and energy processing conversion efficiency.

Table 3. Energy Efficiency Evaluation Form:

Year	2018	2019	2020
The proportion of electricity in the end of consumption	1.6589	1.8785	1.9857
Terminal elimination coal proportion	1.6658	1.8954	1.9687
Growth rate of total energy consumption	1.6548	1.8547	1.9874
Energy subsystem efficiency	1.5698	1.7514	1.8487

As can be seen from Table 3, the proportion of electricity in the final energy consumption

structure has shown a steady and rapid upward trend, while the proportion of coal is still relatively high. change. Therefore, it is necessary to further adjust and optimize the energy consumption structure and increase the improvement of clean energy.

5.Conclusions

Energy is the blood of economic improvement, and the history of human improvement is a history of using energy to promote social change. At present, the three major fossil energy sources of coal, oil and natural gas are still the main sources of primary energy supply. At present, there are three main energy-related issues we are facing: energy supply security, alternative energy improvement, and energy efficiency improvement.

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