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Promotion Potentiality and Optimal Strategies Analysis of Provincial Energy Efficiency in China

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Abstract: In order to meet the dual requirements of economic development and energy consumption, the Chinese government has adopted a series of measures and policies to improve energy efficiency. However, the developing characteristics are not the same in different regions. Thus, it is necessary to analyze the actual energy efficiency levels in a more targeted manner. In this paper, 30 provinces in China will be adopted to study energy efficiency based on the statistical data from National Energy Administration and National Bureau of Statistics. With the trends of Chinese energy consumption and economy development, the Lorenz curve between Chinese energy consumption and GDP is fitted firstly. The Lorenz coefficient (0.1562) shows that the energy allocation in China is neither reasonable nor balanced. Then, by cluster analysis, the regions of different provinces are newly divided into five divisions from the dimensions of economy and energy, i.e., (high development level and high consumption level, HH), (moderate development level and moderate consumption level, MM), (moderate development level and low consumption level, ML), (low development level and low consumption level, LL), and (low development level and moderate consumption level, LM). Based on the division results, the provincial promotion potentialities are estimated quantitatively according to the absolute convergence feature of energy efficiency promotion. The provinces that have more promotion potentialities of energy efficiency are located, such as Hebei (56.29%) in division (HH), Liaoning (38.15%) in division (MM), Anhui (44.17%) in division (ML), Ningxia (71.63%) in division (LL), and Xinjiang (35.26%) in division (LM), According to the different provincial potentialities, energy efficiency in China needs to improve more, but the improvement approaches should be specific and differential. Driven by technology, policy and mechanism, and industrial restructuring, the Chinese economy and energy resources should be integrated afresh to promote the energy efficiency level. Some optimal strategies on energy efficiency promotion are discussed, finally, aiming to provide effective references for the Chinese government to make relative policies. The study proposes a new perspective for provincial energy efficiency research which can also provide a reference for other countries.

Keywords: energy efficiency; regional division; promotion potentiality; strategies; China

1. Introduction

Under environmental pressure and facing the requirements of economic development, energy efficiency has become increasingly significant to government policy in China in response to a range of challenges, such as energy resource scarcity and shortage of the energy supply. Meanwhile, China is in the transitional period of economic restructuring and industrial upgrading. In the past decade, excessive amounts of money were invested into energy-intensive industries. The Chinese energy efficiency level is lower than the world average. Continually increasing energy consumption and a low energy efficiency level have not only caused environmental problems but have also led to

disharmony between economic development and energy consumption. Serious attention should be paid to energy efficiency by the government in China. Hence, it is of great significance to achieve a better understanding of the economy and energy development trends and test the actual energy efficiency level in different regions in order to explore the promotion potentiality of energy efficiency. In this paper, cluster analysis will be used to newly divide the energy efficiency regions according to the economic and energy data of 30 provinces. Then the provincial promotion potentiality of energy efficiency will be calculated via quantitative analysis. A new regional perspective to this problem makes the energy efficiency analysis more targeted. Moreover, this exploration of energy efficiency promotion potentiality is vital for central and local governments to find the common issues in different divisions, which will be helpful to implement measures for the energy consumption, economic development, and the improvement of energy efficiency in China.

2. Literature Review

There are various studies on energy efficiency in recent years. These studies mainly focus on two aspects, i.e., measuring methods of energy efficiency and the empirical studies for energy efficiency improvement. The research methods and studying results will be stated as follows.

(1) Measuring methods of energy efficiency. Various methods are adopted to measure energy efficiency. Take China as a whole, a parallel slacks-based measure was used to examine the energy efficiency based on the data of the economic system [1]. The energy saving potentials for the whole system were defined and the institutional influential factors were also examined. From the perspective of industrial structure, they concluded that the inefficiency of the economic system in China is mainly sourced from the lower energy efficiency performance of the secondary industries. In order to explore the driving factor of energy efficiency, a non-parametric frontier model and a multilevel explanatory analysis were combined to test the energy efficiency in European countries [2]. The result showed that technological improvement was the main driver to industrial energy efficiency performance. From the relationship between economy, environment, and energy efficiency, some papers found that the uncertainty of CO_2 emissions had significant impacts on regional efficiencies [3]. To address this issue, a radial stochastic DEA (Data Development Analysis) model was proposed based on the chance constrained programming. Then, the radial stochastic model was extended to a non-radial model for measuring pure energy use and CO_2 emissions efficiencies. The proposed approach has been applied to evaluate regional efficiencies of energy use and CO_2 emissions in China [4]. Meanwhile, the level of energy efficiency was sketched out and explained from an economic perspective via the theoretical framework [5]. The empirical methods for measuring were tested as well. Some of the empirical studies were summarized and discussed, which had attempted to measure energy efficiency using an economics approach. Additionally, a CGE (Computable General Equilibrium) model was also adopted to investigate the relationship between energy efficiency and economy-wide impacts in the economy-wide energy rebound effects [6]. The result found that with economy-wide energy efficiency improvement on the production side, economy-wide rebound was moderate. Energy efficiency improvements in particular sectors induced quite different economy-wide impacts. This CGE method offered valuable insights for policy-makers aiming to achieve energy conservation through increasing energy efficiency. Relative economic methods were also used to study the energy efficiency, such as shadow price [7].

(2) Empirical studies for energy efficiency improvement. Different empirical studies were also widely discussed aiming to improve energy efficiency. In order to increase the promotion of the energy efficiency level from the energy supply side, the production and end-use energy efficiency was brought into the regional level sustainability targets [8]. They established a solid framework to gather the required data for energy efficiency analysis and its development evaluation. The small Finnish town of Lohja was introduced to show the possible actions linked to the regional energy targets. From the aspect of industrial structure modeling, the contribution

of UK industry to the long-term energy policy targets was analyzed [9]. They found that the industry sector was essential for achieving the overall efficiency commitments and it made a moderate contribution to the expansion of renewable energies mostly through the use of biomass for low-temperature heating services. From the improvement strategies in specific industries, the energy efficiency and its influencing factors were analyzed based on the overall Chinese textile industry [10]. The results showed that the energy efficiency of Fujian's chemical fiber industry had continued to improve yearly, and was currently above the national average in 2014. The low proportion of state-owned and state holding enterprises value, low proportion of coal consumption in the energy structure, industrial scale with a majority of medium-sized and large-sized enterprises, and advanced technology level were the main reasons for the success of energy efficiency promotion of Fujian's chemical fiber industry. Similar analyses were also studied in the automotive industry, manufacturing industry, cement industry, etc. [11–13].

According to the analysis above, many complicated methods were used to find the influencing factors to energy efficiency and the relationships between energy efficiency and other systems. However, the levels and characteristics of energy efficiency in different regions are not described directly, especially of the provinces in China. Thus, in this paper, regions of energy efficiency in China will be newly divided by the different development levels of the economy and energy consumption. Compared with the optimal energy efficiency levels in different divisions, the promotion potentiality of each province will be calculated and the general issues in each division will be proposed. Additionally, empirical examples will be given more than in previous studies. According to different characteristics of energy efficiency in different divisions, promotion strategies will be discussed from the aspects of technology, policy, and industrial restructuring. It will provide more useful information for China's central and local governments to make optimal decisions on both economy and energy industry development in order to promote the provincial energy efficiency levels effectively.

3. Methodology

The research methodology of this study is shown in Figure 1.

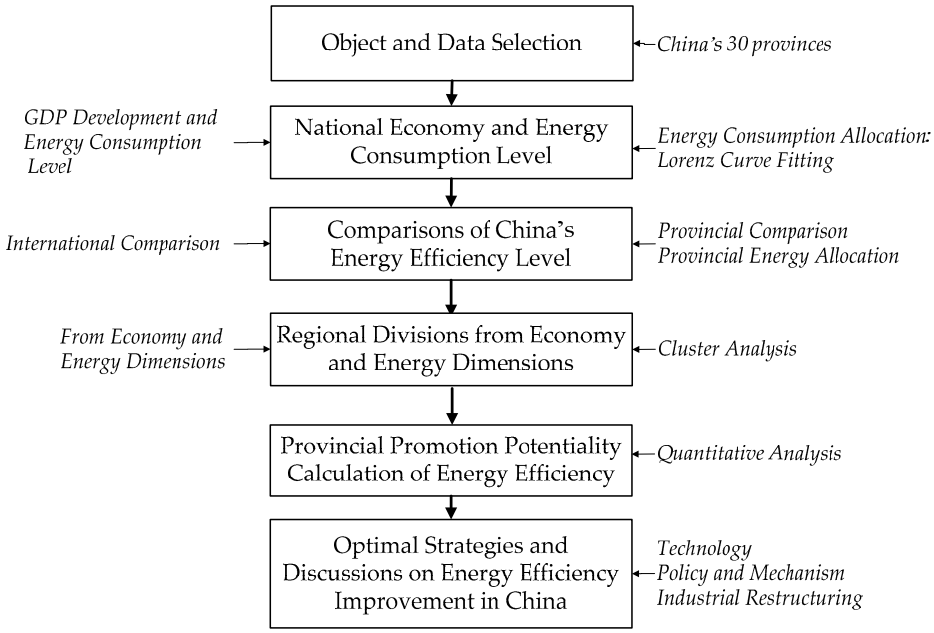

Figure 1. The study process of promotion potentiality on provincial energy efficiency.

First, with an extensive literature survey, the research methodology in this paper was constructed. As two main factors influential to energy efficiency, the economic development and energy

consumption in China's 30 provinces were taken as analysis objects based on statistics from the National Bureau of Statistics, National Development and Reform Commission, and National Energy Administration. With the two dimensions of economic development and energy consumption, the energy efficiency of national and provincial levels was analyzed accordingly.

Second, with the national GDP development and energy consumption data, their developing trends in recent years were used to explain the factors' development situations of energy efficiency in China. By implementing a Lorenz curve, the energy consumption allocation in China was described to show that the energy resources were not allocated well, which may cause serious energy wastage. Then, based on BP (British Petroleum) statistics, the national energy efficiency levels between developed and developing countries were compared in order to evaluate China's energy efficiency level from an international perspective. Finally, in this part, the provincial energy efficiency levels of 30 provinces were explored to find their development trends and gaps.

Third, based on different provincial economic development and energy consumption levels, the regions were newly divided by a cluster analysis method. Then, quantitative analysis was conducted to study the promotion potentiality of energy efficiency. The promotion potentialities were estimated based on the economy and energy data of each province in 2013. The reasons causing provincial energy efficiency gaps in different divisions were particularly discussed. Meanwhile, the limitations of this calculation method were finally presented in this part.

Finally, according to the promotion potentiality analysis results of energy efficiency, some optimal strategies were discussed from three aspects, i.e., technology, policy, and industry. This will provide references for the central and local governments to make decisions to improve China's energy efficiency.

4. Energy Efficiency Development Level Analysis

In this section, China's energy efficiency development level will be analyzed from two aspects. First, as the two main factors influential to the energy efficiency, the development trends of the economy and energy consumption in recent years will be reviewed in order to understand the macro development environment of energy efficiency. For example, through the Lorenz curve, the energy allocation level can be easily seen. Second, based on the international and local statistics, energy efficiency comparisons between China and other countries, and the ones between its provinces, will be studied to lay a foundation for regional divisions and promotion potentiality of provincial energy efficiency. Meanwhile, the Lorenz curves of each province are also given in this section.

4.1. National Economic Development and Energy Consumption

In order to study the provincial energy efficient in China, the overall economic development and energy consumption should be understood briefly. As we know, the economic development level and energy consumption level are the two factors influential to the energy efficiency (or energy intensity). In this section, the recent overall economic development and energy consumption levels in China will be reviewed firstly. Then, via the Lorenz method, the yearly energy allocation efficiency level will be tested. It will be helpful to study the provincial energy efficiency at the macro level. The details are as follows.

(1) Economic development level

Throughout the 21st century, the tendency of economy development in China has been increasing very obviously. Figure 2 [14] shows that the total GDP of China was just less than $2 trillion in 2001, but in 2014, the total GDP of China has reached $10.38 trillion which makes China the world's second largest economy. Compared with 2001, the Chinese economy expanded nearly six times. In terms of economic increase, Chinese economic growth remained at 10% level, on average, for the past decade. The increasing rate even reached 14% in 2007. With the outbreak of the financial crisis in 2008, the development of the Chinese economy has entered into a peaceful period. Especially in the previous three years, the increasing rate was 7.8%, 7.6%, and 7.4%, respectively, in 2012–2014. Adjusting the

economic structure and guaranteeing the quality of economic development were the main causes for this rate change. Considering China's economic size, the slowdown of the GDP's increasing rate is still acceptable. According to the official statistic data, the GDP increasing rate of China in 2015 will remain at 6.9%. The steady growth of the Chinese economy provides strong support for the sustainable development of both the world economy and the regional economy.

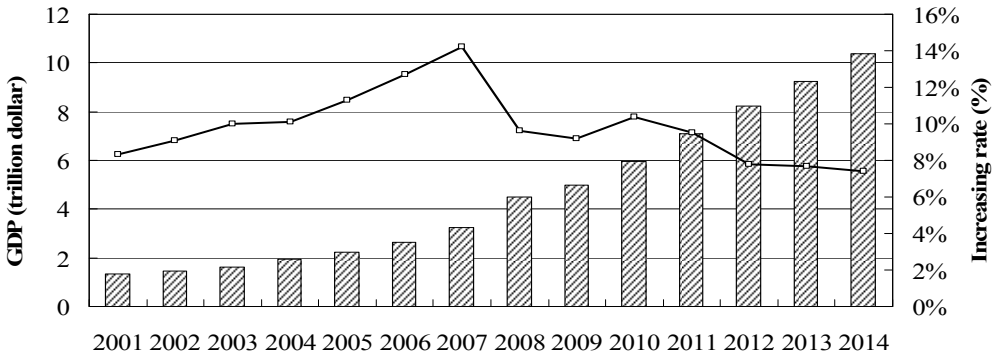

Figure 2. The total economic development and GDP's increasing rate in China from 2001–2014. Source: National Bureau of Statistics of China [14].

(2) Energy consumption level

With the rapid growth of the Chinese economy, the demand for energy is also increasing. The energy consumption from 2001–2014 is shown in Figure 3 [15]. From Figure 3, it shows that there is an increasing energy consumption consistent with economic development. In 2014, the total energy consumption in China has reached 2952.79 million tonnes of oil equivalent (toe). Compared with 2001, the energy consumption has increased by 2.76 times. From the perspective of the energy consumption structure, coal is still the main source of energy consumption, but the consumption proportions of natural gas and renewable energy are also increasing. For example, in 2014, the proportions of natural gas and renewable energy respectively reached 6.2% and 10.7% in total energy consumption. Under the guidance of energy conservation and emission reduction policies, the Chinese energy consumption structure was optimized step-by-step in recent years. The wide and significant uses of clean energy provide possibilities to improve the energy efficiency. Meanwhile, the tendency shows that improving the energy consumption structure has great potential. Apparently, promoting energy efficiency will be helpful to deal with this problem.

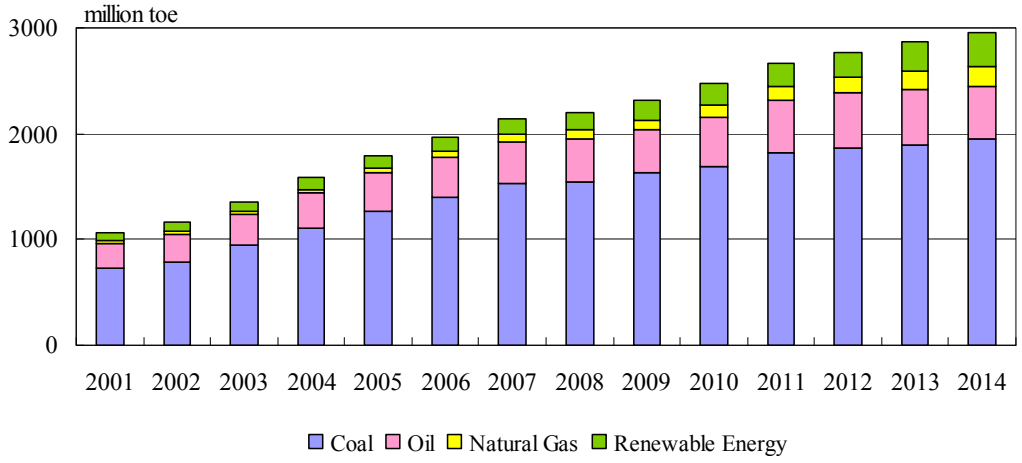

Figure 3. Chinese energy consumption from 2001–2014. Source: Department of Energy Statistics, National Bureau of Statistics of China [15].

(3) Energy consumption and energy allocation level

Energy allocation level is another factor influential to energy efficiency. In China, the energy resources and the energy demand are distributed reversely. The imbalanced distribution is also a cause for different energy efficiency levels in different provinces. Through the economic development and energy consumption analysis, the fitting method of the Lorenz curve is employed to explain the relationships between energy consumption and GDP development levels in recent years. The Lorenz curve was firstly proposed in the early 20th century. It was used to show the equitableness of wealth distribution and the increasing relationship between population and income. With the development of this theory, it was widely used in various fields. It can represent the energy allocation situation in different provinces and also show the national energy allocation situation in different years. In this section, the overall energy allocation situation in recent years will be explored. Thus, the accumulative values of Chinese GDP and energy consumption from 2001–2014 were set as the abscissa and ordinate. The Lorenz curve of Chinese GDP and energy consumption is shown in Figure 4.

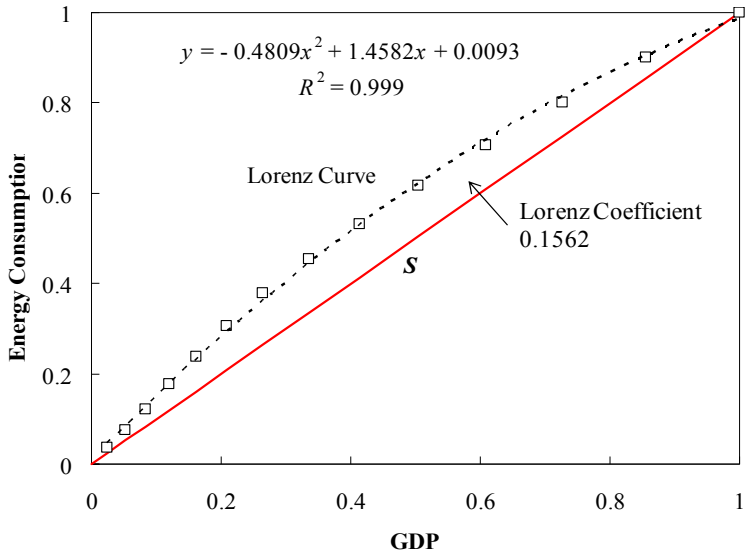

Figure 4. The Lorenz curve of Chinese GDP and energy consumption.

In Figure 4, *S* stands for absolute equality line which is an ideal energy allocation situation. It means that the GDP increases in sync with the energy consumption. Based on the accumulative values of GDP and energy consumption, the Lorenz curve was fitted through a polynomial equation. The fitting equation and the goodness of fit are shown in Figure 4. It can be obviously seen that the Lorenz curve of energy consumption in China is a convex curve which is above the absolute equality line *S*. This curve shows that China consumed more energy in some years with a low energy efficiency level. The area between the Lorenz curve and the absolute equality line represents the overall energy wastage caused by inefficient allocation (Lorenz coefficient is 0.1562). This situation reflects that the energy allocation in China was neither reasonable nor balanced. The fitting result is accordance with the actual economy and energy development situation in China. The extensive economic development mode and the imbalance between the energy supply and demand are the main reasons for the low energy allocation efficiency. Under the circumstances of low energy consumption and rapid economic growth, energy efficiency research plays an important role in finding ways of promoting the energy allocation level.

4.2. Chinese Energy Efficiency Level

With the national economy and energy consumption analysis above, Chinese national and provincial energy efficiency will be studied. Energy efficiency is the ratio of energy input and energy

output. It can be divided into economic energy efficiency and technological energy efficiency. If there is no special instruction, the energy efficiency generally refers to the economic energy efficiency. That is, using GDP to replace the energy output. In this paper, the total quantity of GDP and energy consumption will be used to calculate the energy efficiency via Equation (1):

$$\eta = \frac{GDP_i}{E_i} \quad (1)$$

In Equation (1), GDP_i stands for the GDP level in different countries or provinces. E_i is the total quantity of energy consumption in different countries or provinces. Through Equation (1), China and its provincial energy efficiency levels in recent years will be calculated.

(1) National energy efficiency level

Based on the statistical data [16,17], the comparison of energy efficiency between China and other developed and developing countries is shown in Figure 5.

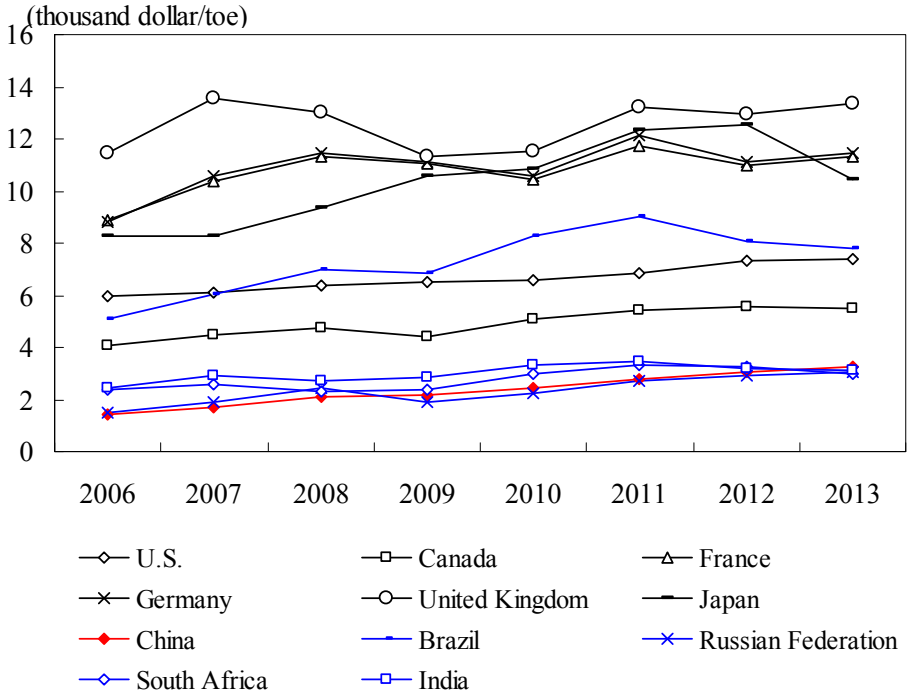

Figure 5. The energy efficiency level comparison between China, developed countries, and BRICS. Source: International Monetary Fund and Britain Petroleum [16,17].

In Figure 5, the energy efficiency levels in most countries have improved. Specifically, in typical developed countries (black lines in Figure 5), the United Kingdom had the highest energy efficiency level. For example, in 2013, 1 toe input can output $13,350 in United Kingdom. Meanwhile, the energy efficiency in Europe was generally higher than that in North America. The energy efficiency in Japan had a similar level with Europe's. Although China's energy efficiency level had improved in recent years, there was a large energy efficiency gap between China and developed countries. In terms of the developing countries in BRICS (blue lines in Figure 5), their energy efficiency levels were relatively lower than those in developed countries from 2006–2013. However, Brazil reached a high energy efficiency level, which has benefited from the greater use of alternative and clean energy resources, such as natural gas and ethanol fuel. In Brazil, 90% of cars are driven by ethanol fuel, reducing 80 million tons carbon dioxide emissions from 2003–2009. China has a similar level of energy efficiency compared with the Russian Federation, South Africa, and India, which rises steadily, but still has much space for improvement.

(2) Provincial energy efficiency level

After the overall energy efficiency analysis, the provincial energy efficiency levels will be focused on China. Based on the statistical data from the National Bureau of Statistics of China, 30 provinces will be chosen as analysis objects, i.e., Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang (due to the incomplete statistical data, Tibet and Taiwan are not taken into account.). Usually, China is divided into three regions by economic development levels and geographical locations, i.e., the eastern region, the central region, and the western region. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The following analysis will rely on the traditional divided regions.

Taking one year as an example, the provincial energy efficiency values in 2013 are shown in Figure 6, which shows that the provinces in the eastern region have high energy efficiency levels. For example, Beijing had the highest level, its energy efficiency was $3.30 thousand per toe in 2013. On the contrary, the provinces in the western region had relatively low energy efficiency levels, e.g., Ningxia, Qinghai, and Xinjiang. The maximum gap between provincial energy efficiency in China in 2013 is $2.70 thousand per toe. It shows that the energy efficiency levels in different provinces are uneven. Thus, it is necessary to find the provincial characteristics of energy efficiency and explore their promotion potentiality in order to design strategies for energy efficiency improvement.

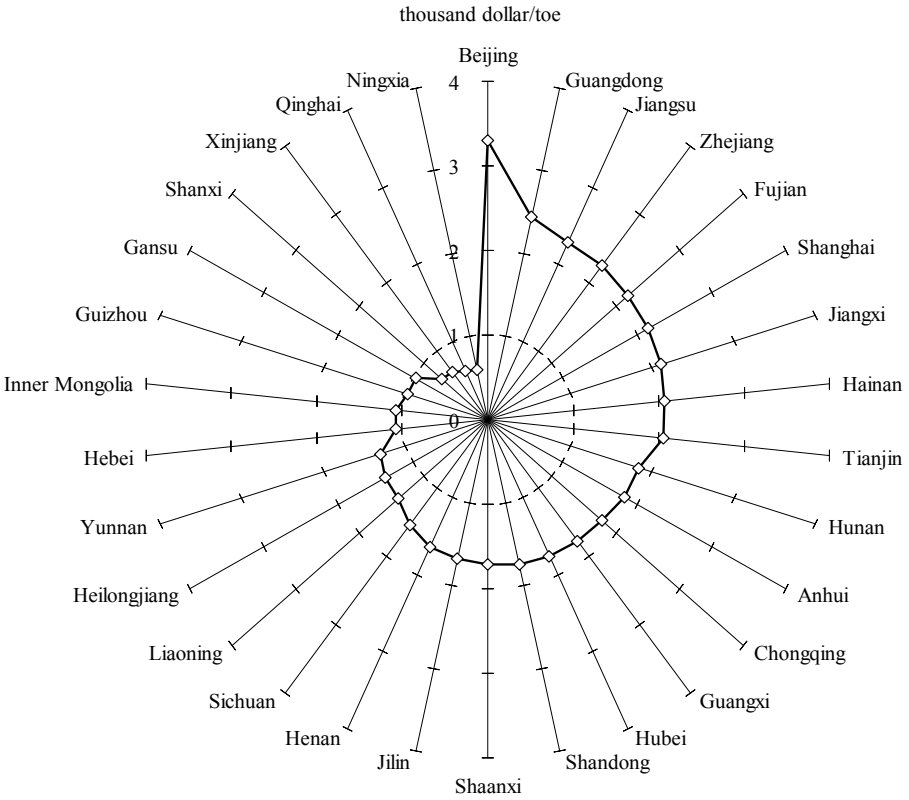

Figure 6. Chinese provincial energy efficiency in 2014.

From the perspective of the historical developments, the provincial energy efficiency levels in China differed. Figure 7 shows that the municipalities under the central government had better energy

efficiency levels, such as Beijing, Shanghai, and Tianjin. In general, the eastern provinces, with high economic development levels, also had steady growths in energy efficiency levels in past years, such as Guangdong, Jiangsu, Zhejiang, and Fujian. The provincial energy efficiency levels in the western region were still low. To some extent, the gap between the energy efficiency levels became larger and larger. For example, the difference between the highest and the lowest was $0.86 thousand per toe in 2005, while this value increased to $2.69 thousand per toe in 2013. Even in the same regions, the gaps of energy efficiency levels still exist. For example, in the eastern region, Beijing's energy efficiency value in 2013 is more than three times than that in Hebei. The differences of economic development, energy consumption, and talent concentration are the main causes for this phenomenon. So, reasonably determining the provincial economic development levels and mining the differences between energy efficiency levels can provide references for the relative guidance policy-making in order to promote the development of energy efficiency levels and avoid the further widening of the efficiency gap.

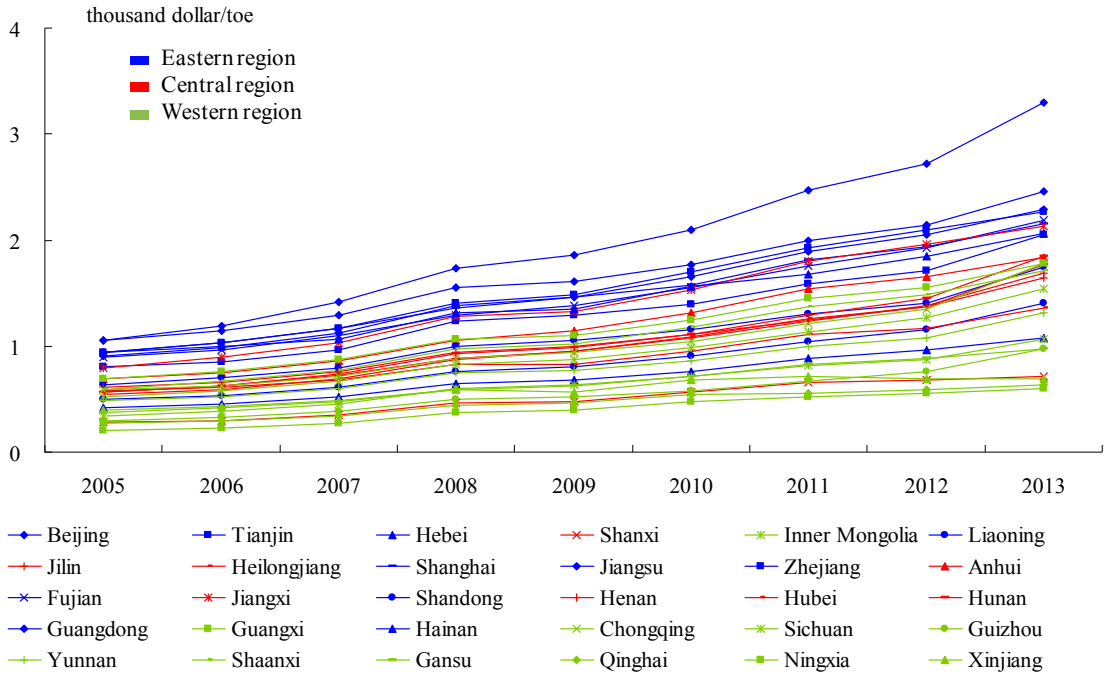

Figure 7. The historical development levels of provincial energy efficiency in China.

Additionally, the differences between provincial energy efficiency levels can also be tested via energy consumption allocation. In Figure 8, the Lorenz curves obviously show that the energy allocation level of the eastern region is closer to the absolute equality line *S*. This means that the equal quantity of energy input can output more GDP in the eastern region. However, from the perspective of energy consumption allocation, Xinjiang obtained an allocation level which is not in accord with the general energy efficiency trends in the western region. The relative value used in the Lorenz curve causes this abnormal result. Thus, a new method for energy efficiency evaluation needs to be studied which can reflect the realities of provincial energy efficiencies.

In summary, China has a relatively low energy efficiency level compared with other countries. Meanwhile, it also has gaps in provincial energy efficiency levels. Therefore, the analyzed regions need to be newly divided considering the energy and economy characteristics in different provinces. The new division will be introduced in the next section. Based on the division result, promotion potentiality of provincial energy efficiency will be calculated.

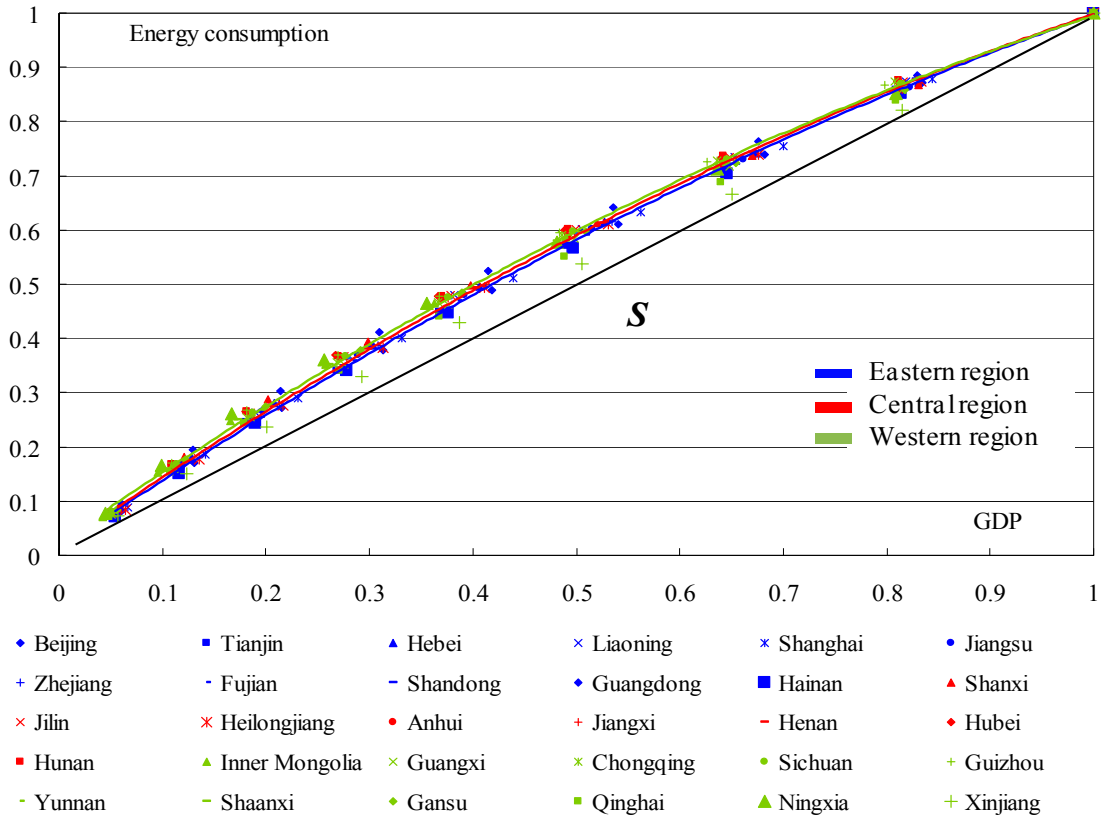

Figure 8. Provincial energy consumption allocation from 2005–2013.

5. Regionalization and Promotion Potentiality of Provincial Energy Efficiency

5.1. Regional Divisions Based on Cluster Analysis

The distribution of energy resources in China is uneven. The energy resources are plentiful in Western and Northeastern China. However, the main energy demands are usually concentrated in the southeast coastal areas. Meanwhile, the economic development level in each province is also different from others. Though energy efficiency may be influenced by many kinds of factors, such as population, transportation, policy, and so on, economic development and energy consumption are the most important factors to it, undeniably. Thus, in the process of provincial energy efficiency research, it is necessary to classify these Chinese provinces effectively from economic and energy consumption dimensions.

According to the common dividing standard, as mentioned in Section 4, China is usually divided into three regions by the economic development levels and geographical locations, i.e., the eastern region, the central region, and the western region. However, the economic development and energy consumption levels in each province have different situations. Even in the same region, the provinces also have gaps on energy efficiency levels. Thus, the regions need to be divided again according to their characteristics of economy and energy consumption.

Based on the provincial data of GDP and energy consumption in 2013, the k-means cluster analysis method was adopted to divide the regions. With the help of the k-means cluster analysis, three clusters were set before classifications and the number of iterations is set as 10. Relying on the criteria of minimum Euclidean distances between samples, the provinces are clustered into three kinds based on the economic dimension. The clustering centers of provincial GDP levels are \$190.77 billion, \$443.24 billion, and \$962.77 billion, respectively. The GDP range of the low development level is from \$35.54–\$275.33 billion, the moderate GDP range is from \$312.98–\$614.53 billion, and the high GDP range is from \$898.93–\$1016.84 billion. Similar to the energy consumption dimension, the clustering

centers of provincial energy consumption are 57.28 million toe, 124.67 million toe, and 210.94 million toe, respectively. Its low, moderate, and high levels are, respectively, from 25.91–81.50 million toe, 102.59–150.65 million toe, and 195.84–243.13 million toe. Through this data processing, 30 provinces with similar economy and energy characteristics were located in nine expected regional divisions. The dividing results are shown in Figure 9. This classification will make the comparison of energy efficiency between different provinces more targeted. The specific analysis on the differences of provincial energy efficiency will be introduced in Section 5.2.

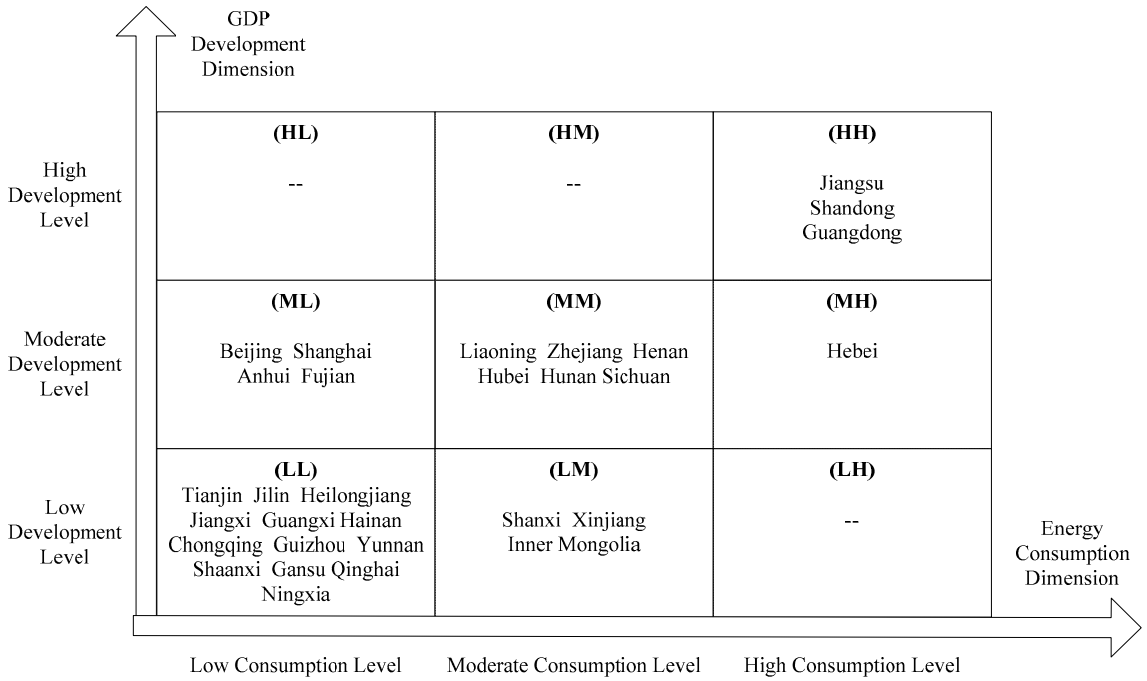

Figure 9. The results of regional divisions with different economic and energy characteristics.

5.2. Promotion Potentiality of Energy Efficiency in Different Regions

According to the dividing results above, under the same level of GDP development or energy consumption, the promotion potentiality of the provincial energy efficiency can be tested via Equation (2):

$$P_i = 1 - \frac{GDP_i}{E_i} / \frac{GDP_{\max}}{E_{\max}} \quad (2)$$

In Equation (2), P_i stands for the promotion potentiality of the energy efficiency in province i. GDP_i/E_i stands for the energy efficiency in province i. $GDP_{\max}/E_{\max}$ is the maximum value in the region that province i belongs to. It is worth noting that the maximum energy efficiency values in different regions still have improvement potentials. They are reference values or regional optimization values in the process of promotion potentiality calculation. Based on the provincial data in 2013, the promotion potentiality of provincial energy efficiency in five available divisions can be calculated, i.e., (high development level and high consumption level, HH), (moderate development level and moderate consumption level, MM), (moderate development level and low consumption level, ML), (low development level and low consumption level, LL), and (low development level and moderate consumption level, LM). The calculation results are shown in Table 1.

Table 1. The promotion potentiality of the provincial energy efficiency in five divisions.

Divisions	Maximum Value (Thousand Dollar/Toe)		Promotion Potentiality (%)	
(HH)	Guangdong	2.46	Jiangsu	6.73%
			Shandong	28.79%
			Hebei [1]	56.29%
(MM)	Zhejiang	2.27	Hunan	18.52%
			Hubei	22.06%
			Henan	27.46%
			Sichuan	32.18%
			Liaoning	38.15%
(ML)	Beijing	3.30	Fujian	33.64%
			Shanghai	34.70%
			Anhui	44.17%
(LL)	Jiangxi	2.13	Hainan	2.78%
			Tianjin	3.58%
			Chongqing	16.43%
			Guangxi	16.44%
			Shaanxi	19.63%
			Jilin	20.59%
			Heilongjiang	35.83%
			Yunnan	38.18%
			Guizhou	54.24%
			Gansu	54.28%
			Qinghai	70.36%
			Ningxia	71.63%
(LM)	Inner Mongolia	1.07	Shanxi	33.01%
			Xinjiang	35.26%

[1] Hebei is merged into the division (HH).

In Equation (2), there is a proved absolute convergence feature in the provincial energy efficiency promotion [18]. In other words, the provincial energy efficiency has the feature that approaches the maximum value in the same division. Based on this law, the promotion potentialities of energy efficiency in each division were calculated. The specific analyses on promotion potentialities of energy efficiency in different divisions are as follows.

(1) In the division (HH), the provinces in this division had high GDP development and energy consumption levels. Guangdong obtained the highest value of energy efficiency. Relative to Guangdong, the promotion potentialities of energy efficiency in Shandong and Hebei are, respectively, 28.79% and 56.29%. The promotion potentiality of Hebei is huge due to there being many energy-intensive industries in it, such as the chemical industry, cement industry, and steel industry. Reducing the energy intensity is a problem to be solved immediately. On the background of Beijing-Tianjin-Hebei integration, Hebei's local government tries to control the overcapacity of these high energy intensive industries and decrease the proportion of the second industry [19].

(2) In the division (MM), the provinces had moderate GDP development and energy consumption levels compared with the ones in division (HH). In this region, Zhejiang had a better energy efficiency level. The promotion potentialities of other provinces are almost from 20% to 30%. Most of the provinces are in central China. These provinces have relatively abundant energy, but they do not create enough economics benefits. Shifting the main energy consumption to the high-tech and service industries may be the effective measures to promote the energy efficiency levels in this division. For example in Henan, Zhengzhou National Hi-tech Industrial Development Zone was constructed in 2004. The zone is aiming at supporting the developments of hi-tech industries with low energy consumption, e.g., the software and information

industry, biological medicine industry, optic-mechanical integration industry, and new materials industry [20]. These strategies provide possibilities for reducing the energy intensity.

(3) In the division (ML), these provinces input lower energy and obrained larger economic output. Take Beijing as an example: many high value-added industries and enterprises are brought together in this city. Meanwhile, the city has a developed tertiary industries; the more prominent characteristics they have, the higher energy efficiency levels they receive. This rule also applies to Shanghai, Fujian, and Anhui. They provide references for the provinces in other divisions to explore suitable development methods. Improving the economic output and adjusting the economic development structure may be good choices for other provinces.

(4) In the division (LL), these provinces had low GDP levels with low energy consumption. Their geographical locations are widely distributed. Jiangxi received a relatively better energy efficiency level. The provinces in the northwest and southwest region have more promotion potentiality. For example, Gansu, Qinghai, and Ningxia have 54.28%, 70.36%, and 71.63% promotion potentiality, respectively. Far inland, most provinces in this division do not have convenient traffic conditions, which is not conducive for trading. Mining new economic growth points are very crucial.

(5) In the division (LM), the provinces received the worst energy efficiency levels. Compared with Inner Mongolia, the energy efficiency promotion potentiality in Xinjiang is 35.26%, similar to the 33.01% in Shanxi. For example, according to the official bulletin from National Bureau of Statistics, National Development and Reform Commission, and National Energy Administration in 2011, the energy intensity in Xinjiang had increased by 6.96% [21]. Xinjiang has abundant energy, such as crude oil, wind power, and solar energy, but sufficient energy production did not bring high benefits. A significant amount of energy was consumed by high energy intensity industries, such as the electrolytic aluminum industry [22]. This is the main reason for the low energy efficiency levels in these provinces. Transferring more energy consumption to high-value added industries is a better way to reduce the energy intensity, e.g., the non-metallic products manufacturing industry [23].

The promotion potentialities between the maximum values of energy efficiency in different divisions are also tested. Compared with Beijing, the promotion potentialities of Guangdong, Zhejiang, Jiangxi, and Inner Mongolia are, respectively, 25.51%, 31.22%, 35.47%, and 67.51%. There are still some gaps relative to the optimal energy efficiency. For Beijing itself, it also has potentiality on energy efficiency promotion. Based on the analysis above, most provinces in China have large energy efficiency promotion potentialities. Under the new developing situations, the central and local governments should take comprehensive measures to promote the energy efficiency levels according to the characteristics in different provinces.

5.3. Limitations of the Calculation Method

Though the method of regionalization can effectively divide the provinces into clusters with the same characteristics, there are still some limitations in the calculation method on the promotion potentialities of provincial energy efficiency. First, with the method shown in Equation (2), the promotion potentiality of maximum value cannot be reflected, i.e., Beijing. In future research, the optimal value of the energy efficiency level will be explored to replace the maximum value according to the real development level of every province. Second, with this method, it does not consider the data's time behaviors. The promotion potentialities are just calculated and compared in one year. The changes of time series on energy efficiency should be focused on in future studies, and sufficient consideration will be given to the dynamic features of provincial economy and energy consumption in order to solve its limitations.

6. Optimal Strategies and Discussions

Overall, economic development and energy consumption are the two core variables influential to Chinese energy efficiency. The strategies will be also studied around these two factors. Based on the actual situations of energy efficiency in China, the government has to improve the energy efficiency level from three aspects, i.e., technology, policy, and industry. In this section, some strategies, measures, and experiences for Chinese energy efficiency optimization will be discussed in order to provide advice and references for political decisions-making.

(1) Technical driving

From the calculation equation, the GDP development level and energy consumption level are two factors influential to the energy efficiency. The discussion about the technical driving aims at finding the ways to optimize the energy consumption and build the technical indexes of energy consumption. Usually, popularizing the energy conserving technology, and eliminating or altering the high energy consumption equipment, are the common methods for promoting the energy efficiency from a technical level [2,24]. With the extended meaning of technology, the promotion of management efficiency, the accumulation of production experience, and the progress of technology innovation are also included [25]. For example, diversified portfolio should be adopted in both supply and demand sides in order to increase the technical investment for energy efficiency promotion and find a balanced and sustainably developing way between technology innovation and energy consumption [26]. On the other hand, the technical standards for energy efficiency are not systematic in China at present. More specific indexes can be broken down to evaluate the contributions of technical efficiency and scale efficiency to energy efficiency [27]. Additionally, the data or information collection and the processing of energy efficiency are also very important [28]. It will be conducive to fully understand the real Chinese development level for energy efficiency improvement.

(2) The guidance of policy and mechanism

Energy conservation and energy efficiency promotion cost a significant amount of money. Most industries or enterprises are reluctant to invest in this field. Thus, the government must support and guide the industries or enterprises through strong policies. Building the target responsibility system and forcing enterprises to eliminate the laggard output capacity can reduce energy consumption in a short time [29]. The economic measures will be effective in the long-term by following the market rules, such as fiscal appropriation, subsidy, and tax preference. Making rules and laws is the basis of energy efficiency improvement measures. The cooperative uses of related measures will have a positive impact on Chinese energy efficiency promotion [30,31]. Through empirical case studies the improvement of energy consumption structure has a great and strong influence on energy efficiency promotion [32]. It may be the core work as a next step for energy efficiency policy-making. Additionally, increasing the stakeholder interactions and improving the legal system by political guidance can also provide effective methods to promote energy efficiency [33].

(3) Industrial restructuring

Optimized industrial restructuring is composed of structural advancement and rationalization. Both of these will influence the energy efficiency promotion to a variable extent. Structural advancement is the process of high-level industrial development, which will establish technology concentration and create more added value [34]. Meanwhile, structural rationalization will bring a reasonable energy distribution. The influences of structural advancement on energy efficiency are more directed than the results caused by structural rationalization [35]. Additionally, note that industrial restructuring is not a unique approach for energy efficiency promotion. On the premise of economic benefit maximization, the local governments in different provinces should adjust their industry structure according to the actual energy efficiency levels. For example, during the 11th Five-Year Plan,

the Chinese provinces gradually released the industrial energy efficiency guidelines to promote the efficiency levels and improve the industrial structure [2]. According to the benchmark values of energy efficiency at home and abroad, the energy consumption limit and access values of different products and processes were set up. The determination of relative guidelines provided objective evaluation standards and quantitative references for different provincial governments to eliminate the disadvantage industries and attract investment for competitive industries. During the 13th Five-Year Plan, the local governments should continue to make more specific and operable guidelines for their industries to promote the energy efficiency. Based on the analysis above, there is a cyclical mechanism in the industrial restructuring and energy efficiency improvement. Bilateral promotions will help the government and industries to develop energy efficiency levels.

7. Conclusions

Understanding the promotion potentiality of energy efficiency is important to the harmonious and sustainable development between the economy and energy systems. In this study, provincial data are collected to analyze the energy efficiency levels in China. The trends of Chinese economic development and energy consumption reveal that the energy allocation in China is uneven. Combined with the different GDP development and energy consumption levels, the target regions of energy efficiency analysis are newly divided via a cluster analysis method. The provinces are classified into five divisions, i.e., (HH), (MM), (ML), (LL), and (LM). Based on this, a quantitative calculation method is employed to estimate the promotion potentiality of each province. The results show that Beijing received the best energy efficiency level (3.30 thousand dollars per toe) in 2013. The levels of Inner Mongolia, Shanxi, and Xinjiang are relatively lower than the others. Most provinces in Western China have significant energy efficiency promoting potentialities. Their lower energy efficiency levels are mainly influenced by their irrational energy and economic structures. Consequently, some optimal strategies and advice are given to the government and industries combined with the analysis results. Three aspects of technical driving, policy guidance, and industrial restructuring are discussed emphatically, aiming to implement specific measures for Chinese energy efficiency promotion at the end of the paper. The strategies can be employed by other developing countries as well for finding methods of energy efficiency promotion. The paper provides a new perspective for studying the provincial energy efficiency from economic and energy characteristics. Exploring the dynamic evaluation function on the promotion potentiality calculation method of energy efficiency is the key to future research.

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