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Research on the Efficiency of Circular Economy Development of Silk Road Economic Belt in China based on Super- Efficiency DEA Model

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Abstract: ***The efficiency of circular economy development of nine provinces in the West along Silk Road Economic Belt in China from 2009 to 2012 is measured using super efficiency DEA method. Results show that:The gap of efficiency of circular economy between different regions is larger ; the average efficiency values of Chongqing, Guang xi, Shaanxi, Yunnan and Xinjiang are reached effective DEA , however, Sichuan, Ningxia, Gansu and Qinhai are not reached effective DEA .The efficiency of circular economy of Sichuan and Ningxia is mainly limited by development scale ,The projection result shows that: Gansu, Qinghai and Xinjiang have input redundancy and output deficiency to a certain degree . Based on the findings, some suggestions are proposed to improve the efficiency of the circular economy development of Silk Road Economic Belt.***

Keywords: Silk Road Economic Belt, circular economy; development efficiency, super efficiency DEA method

1. Research Background

Circular economy has always been a concern of the academic community ,Since the concept was put forward,the domestic scholars have never stopped the investigation and study of circular economy, And published a large number of researchresults .Zeng Shaolun et al. (2009) used DEA to evaluate the scale effectiveness and technical effectiveness of circular economy in China's coal-fired power plants.Qin Zhong et al. (2010) used the super-efficiency DEA model to evaluate the effectiveness of the development of agricultural circular economy in Guangdong Province, and put forward some improvement methods on how to improve and improve the operational efficiency of non-DEA effective areas. Wang Yawei et al. (2010) used data envelopment analysis to evaluate the efficiency of circular economy development in 17 cities in Henan Province, and analyzed the optimization path of urban use projection method with relatively ineffective circular economy .Lvwen Hui and Gao Zhigang (2014) use the gray correlation method and DEA method to evaluate and analyze the development level and efficiency of circular economy in Xinjiang and national provinces of China.Jia Guozhu et al. Used the improved data envelopment analysis model to evaluate the efficiency of circular economy in 31 provinces and cities in China's construction industry from 2002 to 2012. The results show that the efficiency of circular economy in China's construction industry is on the rise and the scale efficiency is gradually becoming the best,but the lack of pure technical efficiency has seriously restricted the development of circular economy in China's construction industry .According to the national development and Reform Commission issued in March 2015 to promote the construction of the Silk Road Economic Zone and Maritime Silk Road in twenty-first Century vision and action plan ,18 provinces and some of the core cities of China has been into the "The Belt and Road" focus on the development of the region,"Silk Road Economic Belt" mainly involves 5 provinces in the northwest and 4 provinces and cities in the southwest. Including Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Chongqing, Sichuan, Yunnan,, a total of 9 regions .This article discusses the "Silk Road Economic Zone" domestic part also refers to the above 9 provinces and cities.

In the past, the research results are quite good, which is of great significance for the study of this paper. In previous studies, most scholars use the traditional DEA model to measure the circular economy efficiency of each region, and do not sort the relatively effective decision-making unit, and the super-efficient DEA model can make up for this defect. In addition, taking into account the current specifically for the "Silk Road economic zone" the development of circular economy efficiency of the study less, Therefore, based on the previous research results, this paper analyzes the efficiency of circular economy development in nine provinces and cities along the Silk Road economic zone by using the super efficient DEA model, So as to provide reference for improving the efficiency of economic development along the provinces and cities and the overall economic development of the economy.

2. Research Methods and the Establishment Of Indicators

In this paper, Super efficiency of DEA is used to evaluate the development efficiency of circular economy in Silk Road economic zone.Before using the DEA method to evaluate the efficiency of circular economy development in the Silk Road economic zone, it is necessary to establish the input and output indicators of the system.In this paper, when we select the specific input indicators and output indicators of circular economy, we have refered to the research literature on the evaluation system of circular economy at home and abroad and take full account of the difficulty of obtaining the index data. The nine provinces along the Silk Road

economic zone are taken as decision unit.Select unit GDP energy consumption (per tons of standard coal / million), unit GDP power consumption (kWh / million), fixed asset investment as a percentage of GDP (%) as input indicators,Per capita GDP (yuan), the proportion of tertiary industry added value of GDP (%), garbage harmless treatment rate (%), industrial solid waste comprehensive utilization rate (%) as output indicators,And constructs the index system of the evaluation of the efficiency of circular economy development in the Silk Road economic zone.See Table 1 :

Table 1: Silk Road economic belt recycling economy development efficiency evaluation index system

Level 1 indicators	Level 2 indicators	Unit
Input indicators	Energy consumption per unit of GDP X1	Ton standard coal / million yuan
	Unit GDP power consumptionX2	KWh / yuan
	The proportion of fixed assets investment to GDP X3	Billion yuan
output indicators	Per capita GDP Y1	yuan
	The proportion of tertiary industry added value to GDP Y2	%
	Garbage harmless treatment rate Y3	%
	industrial solid waste comprehensive utilization rate Y4	%

Taking into account the availability of data (China's regional energy consumption in 2013 data has not yet announced),This paper chooses the input and output data for 2009 - 2012,The data mainly come from "China Statistical Yearbook", "China Energy Statistical Yearbook" and "Statistical Yearbook of the Tertiary Industry".

3. Empirical Research

3.1SE-DEA Circular Economy Efficiency

The efficiency of the recycling economy of each province is measured by the input-oriented hyper-efficiency DEA model. The MaxDEA software is used to calculate the super-efficiency value of the Silk Road economic zone in each province. See table 2:

Table 2: The efficiency of circular economy development along the zone in 2009 - 2012

Provinces	2009	2010	2011	2012	Mean	Ranking
Shaanxi	1.079	1.119	1.092	1.096	1.097	3
Gansu	1.003	0.932	0.848	0.822	0.901	8
Qinghai	0.874	0.896	0.773	0.691	0.809	9
Ningxia	0.972	0.947	1.019	0.899	0.959	7
Xinjiang	1.129	1.153	0.970	0.847	1.025	5
Chongqing	1.618	1.586	1.433	1.567	1.551	1
Sichuan	0.921	0.995	0.982	0.953	0.963	6
Yunnan	0.985	1.061	1.184	1.051	1.070	4
Guangxi	1.146	1.129	1.133	1.143	1.138	2
Mean	1.081	1.091	1.048	1.008	1.057	

It can be seen from Table 2 that the overall development level of circular economy in 9 provinces and autonomous regions along the border area in 2009 and 2012 is higher , the average efficiency value is 1.057.Chongqing, Guangxi, Shaanxi, Yunnan and Xinjiang, the average efficiency value of four years have reached the DEA effective, including Chongqing, Guangxi and Shaanxi over the years the efficiency of the circular economy are greater than 1.Chongqing efficiency value came in first, and four years of efficiency value has been far ahead of other along the region, indicating that the development of circular economy in Chongqing fully aware of the coordination of the entire system, input and output effectiveness have reached the best.Guangxi efficiency value ranked second, and four years has shown a steady trend. Shaanxi as a new starting point of China's Silk Road economic zone and bridgehead, the development of circular economy is relatively stable, the efficiency of the calendar year have reached DEA effective, indicating that the inputs have been fully utilized, and achieved good output.Yunnan in addition to the efficiency value of less than 1 in 2009, the other years are greater than 1, and the overall performance of DEA effective. Xinjiang in 2010 the highest efficiency, the last two years continued to decline in 2012 to a minimum, and DEA invalid. The Sichuan years of circular economy efficiency value is less than 1, but the average is 0.963, close to DEA effective, indicating that the development of circular economy is better. Ningxia in addition to the efficiency of 2011 is greater than 1, the other years are less than 1, the overall performance of DEA is invalid. The development of circular economy in Gansu has been showing a downward trend, the efficiency value is greater than 1 in 2009, the other years are invalid DEA. In the entire economic belt ,Qinghai Province in the development of circular economy efficiency is the lowest, and four years of efficiency values are DEA invalid, indicating that the development of circular economy in Qinghai is still the initial stage, the lack of resources, coupled with the economic backwardness, so the efficiency

value Lower.Overall, 2009-2012 along with nine provinces' efficiency is higher,indicating that the development of circular economy in these areas is better.For the relatively backward development level of Qinghai and Gansu, it is necessary to increase resource investment, improve the efficiency of the recycling economy, especially in recent years, under the construction of Silk Road Economic Belt background. The development of circular economy is even more important.

3.2 Analysis on the efficiency of circular economy development in 2012

In order to further understand the factors that affect the efficiency of the development of circular economy, then the input and output indicators of various regions in the economic belt in 2012 were analyzed, Using DEAP2.1 software, the input and output data are substituted into the BCC model, based on the input oriented angle calculate the comprehensive technical efficiency, pure technical efficiency and scale efficiency of the circular economy development in 9 provinces and autonomous regions.

Table 3.2012 circular economy development efficiency and scale returns in different regions along the strip

Provinces	Comprehensive technical efficiency	pure technical efficiency	Scale efficiency	Returns to scale
Shaanxi	1.000	1.000	1.000	-
Gansu	0.822	0.830	0.991	irs
Qinghai	0.691	0.738	0.937	irs
Ningxia	0.899	1.000	0.899	drs
Xinjiang	0.847	0.898	0.943	irs
Chongqing	1.000	1.000	1.000	-
Sichuan	0.953	1.000	0.953	irs
Yunnan	1.000	1.000	1.000	-
Guangxi	1.000	1.000	1.000	-
Mean	0.913	0.941	0.969	

Note: irs indicates an increase in the scale of returns, drs means the scale of diminishing returns, - means the scale of the same remuneration

3.2.1Comprehensivetechnical efficiency analysis

The comprehensive technical efficiency (also known as the technical efficiency) refers to the overall output efficiency when considering all the factors. Table 3 can be seen in 2012 along the area of circular economy comprehensive technical efficiency to DEA effective areas have four, namely, Shaanxi, Chongqing, Yunnan and Guangxi.Several other areas are shown to be non-DEA effective, including Gansu, Qinghai and Xinjiang, the comprehensive technical efficiency is relatively low,The main reason is that pure technology inefficient and inefficient scale, which to some extent reflects the two regions in the power and energy resources, investment in fixed assets and other aspects of investment is not enough,At the same time, it can be seen that the development of circular economy has a certain relationship with the level of regional economic development. The areas with high economic development are more reasonable in terms of energy utilization and investment in fixed assets, so that higher output can be obtained, Thus more efficient。 Ningxia and Sichuan, the comprehensive technical efficiency of non-DEA is effectively caused by the scale of inefficiency, therefore, from the expansion of circular economy development scale or resource allocation and management of technical level to achieve the development of circular economy.

3.2.2 Pure technical efficiency analysis

Pure technical efficiency refers to the fact that, regardless of the size of the case, the output is minimal and the minimum consumption. Table 3 can be seen in 2012, circular economy, pure technical efficiency to achieve DEA effective in six areas, namely, Shaanxi, Ningxia, Chongqing, Sichuan, Yunnan and Guangxi. Gansu, Qinghai and Xinjiang pure technical efficiency is not high, non-DEA effective area, which is leading to these areas of comprehensive technical inefficiency reasons

3.2.3 Scale efficiency analysis

The scale efficiency is the ratio of the comprehensive technical efficiency and the pure technical efficiency.the scale efficiency value is closer to 1, indicating that the scale is more effective. It can be seen from Table 3 that the scale efficiency of circular economy in 2012 is 0.969, indicating that the scale efficiency of circular economy along the zone is at a good level as a whole. There are 4 areas of scale efficiency in DEA, namely Shaanxi, Chongqing, Yunnan and Guangxi. Gansu, Qinghai, Ningxia, Xinjiang and Sichuan scale efficiency is not DEA effective. From the point of view of scale returns, Gansu, Qinghai, Xinjiang and Sichuan and other places are in the increasing stage, that is, if the increase in investment, the output will be higher than the input of the same multiple growth. Therefore, if we want to improve the efficiency of circular economy in these areas, we can increase the amount of investment in resources and expand the scale of the development of circular economy. Thus, in the construction of the Silk Road Economic Zone, capital, energy can still play a huge role, but should pay attention to environmental protection. Ningxia scale diminishing returns, indicating that the current investment resources are relatively adequate, even if the expansion of the scale, the output will not be higher than the input multiplier growth, should focus on resource allocation,

recycling economy and other aspects of efficiency, to achieve further development of circular economy.

Table 4: Analysis of input-output slack variants along the belt

Provinces	Slack variants under variable returns to scale						
	S_1—	S_2—	S_3—	S_1+	S_2+	S_3+	S_4+
Shaanxi	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gansu	0.061	0.032	0.000	3348.788	0.000	43.951	0.000
Qinghai	0.530	0.163	0.000	0.000	3.432	3.300	4.409
Ningxia	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Xinjiang	0.576	0.060	0.000	0.000	0.755	14.496	10.797
Chongqing	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sichuan	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yunnan	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Guangxi	0.000	0.000	0.000	0.000	0.000	0.000	0.000

According to the Slack variants of variable returns to scale, Shaanxi, Ningxia, Chongqing, Sichuan, Yunnan are all 0,Indicating that there is no investment in these areas can be reduced, there is no need to increase the output, energy and capital have been effectively used, and achieved maximum output. While the Gansu, Qinghai and Xinjiang regions $S^- \neq 0$和$S^+ \neq 0$，There is a lack of input and output. Then do the projection analysis of these three areas.

Table 5: Non-DEA effective area projection analysis

Provinces	*X1*	*X2*	*X3*	*Y1*	*Y2*	*Y3*	*Y4*
Gansu	-4.92%	-18.18%		+15.24%		+105.45%	
Qinghai	-28.47%	-51.26%			+10.40%	+3.69%	+7.94%
Xinjiang	-36.55%	-41.38%			+2.09%	+18.41%	+20.94%

An projection analysis of input output for non DEA effective area, As shown in Table 5, Gansu, Qinghai and Xinjiang in the unit GDP energy consumption and unit GDP power consumption are redundant. In the case of the same level of output, Gansu unit GDP energy consumption and unit GDP power consumption can be reduced by 4.92% and 18.18%,If you want to keep the investment structure unchanged, Gansu's per capita GDP should be increased by 15.24%, and the improvement of the harmless treatment rate of living garbage is up to 105.45%.This shows that the energy efficiency in Gansu area has yet to be improved; the economic side, need to further improve the per capita GDP; the environment, the problem of garbage disposal is urgently needed to be resolved. Therefore, it is necessary to strengthen the management of environmental pollutants and improve the utilization of pollutants, otherwise it will seriously affect the sustainability of the development of circular economy. In order to achieve the relative DEA effective, the unit GDP energy consumption and unit GDP electricity consumption in Qinghai should be reduced by 28.47% and 51.26%,the proportion of tertiary industry added value increased by 10.40%, the harmless treatment rate of domestic garbage increased by 3.69% Solid waste utilization increased by 7.94%.Therefore, Qinghai should pay attention to energy conservation and effective use at the same time, not only need to vigorously develop energy resources and power resources, and must vigorously develop the tertiary industry, expand the industrial scale, accelerate the optimization and upgrading of economic structure, at the same time, need to reduce pollutants Emissions, improve the utilization rate of waste. Xinjiang and Qinghai are similar, the input and output should make appropriate adjustments according to the projection results.

4. Conclusion and Suggestions

Based on the panel data of nine provinces and cities in the Silk Road Economic Zone from 2009 to 2012, this paper uses the super efficient DEA model to measure and analyze the efficiency of circular economy development of the Silk Road economic belt, and draw the following conclusions and suggestions:

1) The overall development level of circular economy along the economic belt is higher, Chongqing, Guangxi, Shaanxi, Yunnan and Xinjiang comprehensive technical efficiency average reached DEA effective; For the pure technical efficiency and scale inefficient Sichuan and Ningxia and other places, should make full use of the opportunity to build the Silk Road economic zone, take the initiative to accept high-efficiency areas of radiation, increase resource investment and optimize the allocation of resources, and actively attract domestic and foreign Investment, expand the scale of development. For pure technical efficiency and scale efficiency are ineffective in Gansu, Qinghai and Xinjiang, should take the initiative to the level of development of circular economy in the region to learn more experience, increase investment in circular economy resources, adjust the industrial structure, expand the scale of development of circular economy.

2) From the non-DEA effective area projection analysis we can see:The economic development of Gansu, Qinghai and Xinjiang is still in the high consumption of energy.This

relative dependence makes the production cost of enterprises affected by the fluctuation of energy price, which requires the government to give full play to the role of radiation and effective provinces, promote technology development,making energy-saving emission reduction to achieve new breakthroughs.Qinghai and Xinjiang, the tertiary industry added value accounted for the proportion of GDP output shortage, as a low input, small pollution, quick effect of the tertiary industry,Qinghai and Xinjiang should increase its proportion in GDP, and further improve the city's domestic waste Processing facilities.At the same time, the need to increase the intensity of environmental pollution control, reduce pollutant emissions, improve waste utilization.

3) Through the use of super-efficient DEA model, it can effectively distinguish the efficiency of the region between the traditional DEA model can not distinguish between 1 regions of the efficiency level, more scientific distinction the ranking of the regional circular economy efficiency, in order to improve the development of the circular economy of the Silk Road economy to provide a certain theoretical basis.

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