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Circular Economy Efficiency and Influencing Factors of Chemical Industry in China

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This paper aims to study the current circular economy efficiency and influencing factors in the domestic chemical industry. To this end, the comprehensive analysis was conducted about the economic industry chain, industrial symbiosis, modes, eco-efficiency and influencing factors of the circular economy in the chemical industry. Besides, the model of the natural ecosystem was introduced, and key indicators were used to evaluate the circular economy. The results show that the main influencing factors on the healthy and sustainable development of the chemical industry are the pollutants emissions and the resources consumption, which are inconsistent with the concept of energy conservation and environmental protection advocated under the current social and economic development. Through the analysis and research on the information and influencing factors involved in circular economy, it's concluded that in order to realize the circular economy of the chemical industry, the human's demands for resources should be integrated and the emission of pollutants should be reduced by replacing the traditional linearly-growing economy dependent on resources consumption with circular economy of ecological resources. Thus, the economic activities shall be carried on through the promotion and application of the natural ecosystem model so as to realize the common development of the economy and the environment.

1. Introduction

With the development of national economy, the importance of the chemical industry has been highlighted increasingly, and its level of development directly affects the downstream industries such as the light industry, textile, telecommunication, automobile, and building materials. Since the reform and opening up, China's economy has developed rapidly, esp., the chemical and petroleum industries have also achieved remarkable development. Although the development time of China's chemical products is short, there is no denying that the rapid development of the chemical industry has a far-reaching impact on the promotion of social development and national economy. In modern petrochemical industry, synthetic material products are mainly used, such as synthetic fibres, synthetic rubber and synthetic resins, and the raw materials of these synthetic materials are natural gas and petroleum. Also, many of the material products produced in the chemical industry are basic materials for the development of different industries such as construction, agriculture, transportation, electronics and machinery etc. With the continuous expansion of their development scale, they have also created a large number of employment opportunities. In addition, in the development of the information industry and the knowledge economy, chemical products can provide strong supports and promote their sound development. Therefore, chemical product plays an irreplaceable role in the current social and economic development. It is of great significance to study this industry's circular economy efficiency and influencing factors.

To further promote the development of the chemical industry, it's essential to resolve the contradictions between the rapid economic development, resources, and environment during the current economic development. In the 18th National Congress of CPC, it has clearly proposed that the construction and development of ecological civilization construction is of great significance to promoting the sound development of the economy, and harmonizing the development of the economy, environment, and resources, and it is also an important measure to maximize the use of resources. The propaganda effect of resource conservation should be strengthened, so that people can recognize the importance of resource conservation for balancing

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economic and environmental development and reduce the use of water and land resources. The efficient resource integration is achieved by intensive and economical use of resources, so as to facilitate the recycling, reduction and reuse of consumption, circulation, and production processes. This shall promote the development of circular economy. Therefore, it is necessary to strengthen the research on the circular economy efficiency and influencing factors in the chemical industry.

2. Literature review

The term "circular economy" was put forward by the American economist in 1960s. In the large system of human, natural resources and science and technology, the linearly growing economy, which relies on the consumption of resources, is transformed into the economy developed by the source cycle in the whole process of resource input, enterprise production, product consumption and discarding. Under the guidance of this idea, many foreign scholars and institutions have put forward some theories for developing circular economy in chemical industry.

From the lessons of the past, human beings have gradually realized that it is not feasible only focusing on economic benefits and neglecting ecological benefits. The traditional development model cannot be continued only seeking to meet the needs of contemporary people, but not taking into account the interests of future generations. As a result, it is necessary to change ideas. Bocken and others carried out sustainable development with a good ecological environment as basis, balanced economic development as condition, advanced science and technology as driving force, and comprehensive social benefits as the goal. The balance between environment and development is the basic sign to determine the healthy development level of a country and region (Bocken et al., 2017). Carrying out the strategy of sustainable development is the way to achieve a balance between the two parts, and developing circular economy is an important guarantee for achieving sustainable development. Therefore, the development of circular economy should be placed in an important position corresponding to economic development. Through the rapid development of the chemical industry, Jović and others made outstanding contributions to meet the economic construction of China and improve the living standard of the people. However, at the same time, a large amount of resources were consumed and a large amount of pollutants were produced (Jović et al., 2016). If the current traditional production mode is developed, the excessive growth of the chemical industry will lead to the exhaustion of resources and the deterioration of the ecology, which will directly jeopardize the demand for the next generation of chemical products and endanger the development of the chemical industry. Kits integrated clean production, comprehensive utilization of resources, ecological design and sustainable consumption, and sought the development model of "promoting coordination and harmony between human and nature". This is an important way to realize the sustainable development of chemical industry and the inevitable requirement of implementing the scientific outlook on development and building a socialist harmonious society (Kits, 2017).

As an energy and basic raw material industry, the chemical industry plays an important role in the development of the national economy. Its development level affects the development of many industries, such as communication, building materials, automobiles, light industry and textile industry. After 27 years of reform and opening up, especially in recent years, with the continuous and rapid economic development of China, the oil and chemical industry have also made great progress and remarkable achievements. Możeński stated that the history of the development of chemical products in China is not long, but it has a very close relationship with national economy and social development. The petrochemical industry of synthetic materials, such as synthetic resin, synthetic fiber, synthetic rubber, and other synthetic materials, with oil and natural gas as raw materials, is the current generation industry to guide and drive the other national economy. The development of industry, with strong support and radiation, provided essential basic materials for the development of agriculture, machinery, transportation, electronics and construction industries, and also created a large number of employment opportunities (Możeński, 2017).

The domestic research on circular economy started in 1990s. The research done by Rogerson is still in the definition stage of the meaning and significance of the circular economy, and it also involved the specific application and implementation areas related to the circular economy, such as technology, law, law and regulations (Rogerson, 2016). This is mainly reflected in the following aspects: firstly, the study of the connotation of circular economy. Sadhukhan thought that circular economy was essentially a kind of ecological economy, carrying forward the harmony thought of heaven and man, absorbing nutrition and theoretical argument from Chinese traditional culture, referring to "Economic System Cybernetics" in the scientific basis of circular economy, and putting forward a new noun - "circular economics" (Sadhukhan, 2017); secondly, it is the study of the evaluation system of circular economy; thirdly, it is the research on the application level of circular economy; the fourth is about the research on circular economy and the progress of science and technology (Editors, 2016); the last is about the study of circular economy and the adjustment of law. The countermeasures for the development of circular economy proposed by many researchers can be

summarized as following: strengthening the macro guidance of circular economy; insisting on promoting the development of circular economy according to law; strengthening the structural adjustment and technological transformation with the main content of circular economy; speeding up the development, demonstration and promotion application of circular economy and technology; establishing green GDP accounting system; carrying out extensive publicity and education of circular economy. Wie and Moon pointed out that the environment and resources were the core of the circular economy. The main characteristics of the circular economy were the conservation of resources and the protection of the environment. Moreover, the conservation of resources and the protection of the environment were the concept of circular economy throughout the economy (Wie and Moon, 2017). The circular economy takes the whole economic system as a special form of the ecosystem. The ultimate aim is to improve the economic system, make it compatible with the biosphere, and ultimately achieve the sustainable development of human beings.

To sum up, in the above research work, the application of chemical industry and circular economy in China are mainly studied and promoted. It will make use of the chemical industry to induce and promote the environment of China, and integrate clean production, comprehensive utilization of resources, ecological design and sustainable consumption, and pursue ecological and chemical development model of "promoting the coordination and harmony between human and nature". It is an important way to realize the sustainable development of the chemical industry. It is also the necessary requirement to implement the scientific outlook on development and build a socialist harmonious society. Therefore, based on the above situation, the efficiency and influencing factors of China's chemical industry are focused on. As an energy and basic raw material industry, the chemical industry plays an important role in the development of national economy. Its development level affects many industries, such as downstream communications, building materials, automobiles, light industry and textile industries development.

3. Methods

In this paper, the chemical circular economy system was deconstructed into three subsystems: economic subsystem, social subsystem and ecological subsystem. On this basis, the network DEA model considering unintended output was constructed to measure the efficiency of China’s chemical circular economy, then regional comparative analysis and convergence test were conducted to explore the influencing factors of the circular economy efficiency, and finally relevant suggestions were made. For DEA model: assuming that there are n independent decision units in a particular production system DMUj (j=l,2,...,n), there are m inputs in each decision unit (DMU), Xj=(x1j,x2j) ,,...,xnj)T, to produces s kinds of products Yj=(y1j,2j,...,ysj)T, so, all the production activities of a decision unit (DMU) can be represented by (x, y′).

Farrell et al. proposed the concept of production frontier in order to evaluate the economic output efficiency of each DMU. Only by measuring the distance between each production point and the production frontier, the efficiency of the DMU can be measured; the smaller the distance, the higher the efficiency and the lower the ineffectiveness of the DMU being measured, otherwise, the efficiency shall be lower; when the distance between the production point and the production front is zero, the production point is effective, that is, the production point is on the production frontier. The selected influencing factors were used to build the Tobit regression model with the following formula: $CEEit=\beta0+\beta1\ln(R \& D)it+\beta2\ln(Klr)it+\beta3Rueit+\beta4Regit+\beta5Epit+\beta6R1it+\beta7R2it+\varepsilon it$

4. Results and analysis

4.1 Economic sub-system

The economic sub-system measures the economic development capability of the chemical industry. Input indicators should be considered from the human, material, energy, and technical aspects. Output indicators should consider the “good” output and “bad” output mentioned earlier. Therefore, the input indicators of this subsystem include installed capacity, scientific and technological input, consumption of standard coal, employees, and comprehensive utilization of solid waste; output indicators include chemical generation, effective patents, solid waste generation, smoke, SO2, NOX, Carbon dioxide (CO2) production. Besides, considering that the DEA method requires as many decision-making units as possible and as few input-output indicators as possible, this paper selects the improved entropy method to integrate the amount of solid waste generated, smoke, dust, SO2, and NOX emissions into one indicator. Figure 1 shows the efficiency of the chemical circular economy in the eastern, central and western regions between 2007 and 2013. Figure 2 shows the national chemical circular economy efficiency between 2008 and 2013, where white is economic efficiency, gray is social efficiency, and black is ecological efficiency.

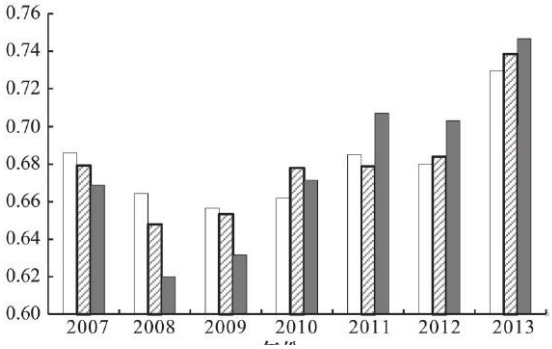

Figure 1: Efficiency of the chemical circular economy in the central and western regions from 2007 to 2013

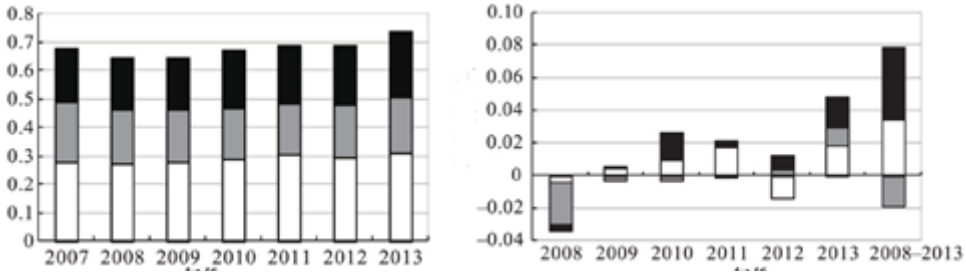

Figure 2: Efficiency of the national chemical circular economy from 2008 to 2013

4.2 Social sub-system

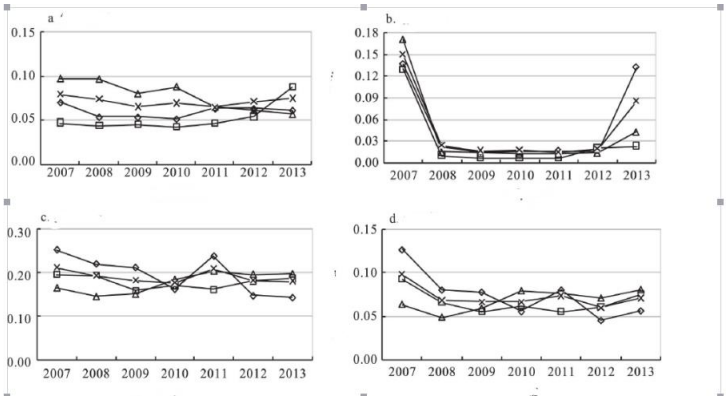

Figure 3: Convergence test results of chemical circular economy efficiency from 2007 to 2013

Table 1: The mean value of circular economy efficiency and the structure of each subsystem of the chemical industry in the eastern and western regions from 2007 to 2013

	Circular economy efficiency value				Contribution rate of each subsystem /%			
	Economic efficiency	Social efficiency	Ecological efficiency	The overall efficiency	economic	Social	Ecological	The overall
In the east	0.892	0.567	0.583	0.681	43.7	27.8	28.5	100
In the middle	0.834	0.570	0.635	0.680	40.9	27.9	31.2	100
In the west	0.889	0.556	0.591	0.673	43.7	27.3	29.0	100

Table 2: The fluctuation value of the economic efficiency and the structure of each subsystem of the chemical cycle in the eastern and western regions from 2007 to 2013

	Fluctuation value of efficiency of circular economy				Each subsystem volatility ratio /%			
	△Economic	△Social	△Ecological	△As a whole	economic	Social	Ecological	As a whole
In the east	0.035	-0.010	0.019	0.681	79.9	-22.7	42.9	100
In the middle	0.028	-0.024	0.053	0.680	49.0	-42.7	93.7	100
In the west	0.041	-0.024	0.061	0.673	52.5	-30.5	78.0	100

Social subsystem measures the social value of the chemical industry. It's linked with the economic and ecological subsystems. Therefore, the input indicators of this subsystem include chemical power generation, solid waste disposal, SO2, NOX, and soot removal; output indicators include taxation, electricity consumption, domestic garbage removal volume, and employees. Figure 3 shows the results of the convergence test for the chemical circular economy efficiency during 2007-2013, a: economic efficiency, b: social efficiency, c: eco-efficiency, d: overall efficiency

4.3 Ecological subsystem

The ecological subsystem measures the environmental pollution and governance level in the chemical industry. The indicators were selected from the perspective of pollution emissions and environmental governance. The selected input indicators include the amount of solid waste generated, the amount of smoke, SO2, NOX, and CO2 generated, and the number of waste gas treatment facilities, electricity consumption, domestic waste removal and transportation; output indicators include comprehensive utilization of solid waste and disposal, SO2, NOX and dust removal, smoke, SO2, NOX, CO2 emissions. Besides, the entropy method was used to integrate the four indicators of solid waste disposal amount and the amount of soot, SO2, and NOX removal into one indicator

4.4 Selection of influencing factors

Table 3: Estimation results of influencing variables of thermal power circular economic efficiency

variable	Coefficient estimate	Standard error of	T value	P values
ln（R&D)	-0.018	0.008	-2.11	0.036**
lnKlr	0.021	0.008	2.65	0.009***
Rue	-0.072	0.035	-2.06	0.041**
Reg	-0.028	0.006	-4.30	0.000***
RMPI	0.178	0.059	3.00	0.003***
R1	-0.043	0.017	-2.59	0.010***
R2	-0.088	0.018	-4.87	0.000***
Constants	0.439	0.103	4.27	0.000***

Note: ***, **, * are significant at the levels of 1%, 5%, and 10%, respectively

The circular economy efficiency value is discrete, and it is between 0 and 1, with the characteristics of being truncated, thus, the Tobit model in the maximum likelihood method (truncated regression model) was proposed. The application expression is: Y={Y*=βX+μ Y*>00 Y*≤0, where, Y* is the truncated explanatory variable vector, Y is the efficiency vector, X is the explanatory variable vector; β is the regression parameter vector, and μ is the error term, and μ ~(0, δ2). According to the existing research and data availability, the influencing factors selected in this paper include: (1) Scientific research input ln (R&D). It's represented by the logarithm of per-capita fiscal science and technology spending to measure the regional science and technology investment, which is expected to have a positive impact on the circular economy efficiency of the chemical industry. (2) Elemental endowment structure lnKlr. It's expressed by the ratio of installed capacity to employees, where the installed capacity is one key indicator representing the investment scale of chemical plant. The increase or decrease of the shares in production factors such as capital and labour etc. is of great significance for improving the production efficiency of the company, and the impact on the efficiency of the circular economy in the chemical industry still remains to be confirmed. (3) Resource recycling utilization rate Rue. Solid waste utilization was selected to denote the Rue. The recycling of solid waste can not only reduce the pollution to the environment, but also improve the resource utilization, and bring additional economic

benefits to the company. It is expected that it has a positive correlation with the cyclical economic benefits of the chemical industry. (4) Environmental regulation intensity Reg. The logarithm of the use of treatment facilities for waste gas emissions was selected to denote Reg. Environmental regulation not only reflects the input of corporate pollution control, but also represents the government's environmental control efforts. The impact on the efficiency of circular economy remains to be verified. (5) Source price RMPI. The purchase price index of raw materials, fuels, and power of industrial enterprises was used to denote RMPI. The fuel cost in the chemical industry accounts for a large proportion of the production cost. Changes in the price of fuel will directly affect the unit returns and business climate of the chemical companies, and the impact of circular economy efficiency needs further verification.

5. Conclusions

Based on the DEA model, this paper measures and analyzes the circular economic efficiency of the chemical industry from 2007 to 2013. Then, it conducts in-depth research of the influencing factors on the efficiency of the chemical industry's circular economy. Finally, through the introduction of Tobit regression analysis and verification, the key influencing factors were determined. After a series of studies, the following conclusions have been drawn:

(1) At present, China's chemical industry has an average circular economy efficiency of 0.680, at a relatively low level, so there is room for improvement. Comparing the efficiency of social subsystems, ecological subsystems and economic subsystems, and circular economy systems, it's found that the main reason affecting the development of circular economy in the chemical industry is the low efficiency of the two subsystems: ecology and society.

(2) The analysis of the influencing factors shows that in the circular economy efficiency of the chemical industry, when the energy price changes, the efficiency will also change accordingly, and the factor endowment structure also has a significant positive impact on its efficiency. The environmental regulations intensity, resource recycling rate, and scientific research input have a significant negative impact on the efficiency of circular economy in the chemical industry.

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