Research on the Impact of Plastic Recycling Industry on Greenhouse Gas Emissions

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Abstract. With the introduction of the circular economy and the goal setting of the Paris Agreement, greenhouse gas emission reduction is facing huge challenges. The recycling of waste plastics is closely related to the reduction of greenhouse gas emissions. The input-output model was used to quantify the relationship between the development of China's plastic recycling industry and the reduction of greenhouse gas emissions, and relevant recommendations were made.

Keywords: waste plastics; recycling technology; greenhouse gases.

1. Introduction
Circular economy refers to an economic system designed for the purpose of reproducing and maximizing the use of products in the economic system. My country's circular economy system includes improving resource utilization efficiency and setting emission reduction targets. The circular economy policy in the waste plastic recycling industry has alleviated the problem of plastic pollution and promoted the reduction of greenhouse gas emissions. The use of recycled plastics to replace virgin plastics plays an important role in reducing greenhouse gas emissions. Due to the complexity of the waste plastic supply chain, regional research on the relationship between waste plastic and greenhouse gas emissions is very limited. This study analyzes the development trajectory of waste plastic emissions to better understand the interaction between greenhouse gas emissions and waste plastic recycling, and to predict the future development trend of waste plastic recycling.

2. Research background
2.1. Assessment of Greenhouse Gas Emissions
In order to study the impact of greenhouse gas emission reduction on the plastic waste recycling industry, the environmental input-output model was used to analyze energy consumption from the perspective of the supply industry chain. The environmental input-output model is derived from the classic Leontief input-output model, which is used to analyze the interaction between different industries in the modern economy.

The original environmental input-output model is:

\[ X = Z + y = AX + y \] (1)
In formula (1): $X$ is the total economic output; $Z$ is the intermediate demand; $y$ is the final demand seek; $A$ is the interaction between different economic industries.

The effect of waste plastic recycling industry and greenhouse gas emissions is shown in formula (2):

$$E_m = F(1-A)^{FD}$$

(2)

In formula (2): $E_m$ is the impact of waste plastic recycling on greenhouse gas emission reduction impact; $F$ is the influencing factor, that is, greenhouse gas emission reduction and waste plastic recycling output ratio; $A$ is the direct consumption factor matrix; $FD$ is the final demand. In the formula, assume that the economic output of other factors is zero.

2.2. Identify the driving factors

The environmental input-output model has a wide range of applications in the analysis of environmental impacts. It is set to explore the influencing factors, including the relationship between human mobility and technology. Assuming influencing factors = population $\times$ mobility $\times$ technology, the original model adds exponential decomposition analysis, and the improved model is used to effectively identify the relationship between the driving effects of different environmental impacts.

$$IPAT = P \times S \times R \times E \times T$$

(3)

In formula (3): $IPAT$ is the greenhouse brought by the development of waste plastic recycling industry driving factor of gas emission reduction, the gross national product is used to measure the overall economic output volume; $P$ is the number of employed people in the industry; $M_t$ is the daily plastic waste production yield; $M_t$ is the recycling ratio; $E_m$ is the development of waste plastic recycling industry reduction in greenhouse gas emissions.

$$P = P_R$$

(4)

In formula (4): $P$ is the demographic factor, reflecting the number of people employed in the plastic recycling industry the impact of the number on the reduction of greenhouse gas emissions. The higher the $P$ value, the greater the impact of human resources on emission reduction the higher the degree of sharing.

$$S = \frac{M_t}{P_R}$$

(5)

In formula (5): $S$ is the scale effect factor, which is produced from overall plastic waste measured by the ratio of the employed population in the industry. The higher the $S$ value, the greater the potential room for greenhouse gas reduction.

$$E = \frac{GDP}{M_t}$$

(6)

In formula (6): $E$ is the economic benefit factor, which is the unit value of economic benefit in the field of waste plastic recycling. The higher the $E$ value, the greater the economic value of the waste plastic recycling industry.

$$T = \frac{E_m}{GDP}$$

(7)

In formula (7): $T$ is a technological factor, which is the amount of greenhouse gas emission reduction per unit GDP, which can be used to measure the effect of technological factors in the industry.

$$IPAT = P \times S \times R \times E \times T$$

(8)

Compared with the traditional IPAT formula, the 3 factors in the original model are expanded to 5 factors, reflecting the contribution of the development of the plastic recycling industry to greenhouse gas emission reduction.
2.3. Quantitative analysis of exponential decomposition model

The processing of the model is usually two typical analysis methods: structural decomposition and exponential decomposition. Each analysis method has advantages and disadvantages. Structured decomposition can quantify changes in basic resources in a model that contains a large number of independent variables, such as economic growth, energy, and pollutant emissions; while exponential decomposition methods are more dependent on the accuracy of industrial organization data. If structured decomposition is used, accurate input-output data tables need to be obtained, while exponential decomposition is not required. Up to now, the input-output data table of China's waste plastic recycling industry is not available, so this study uses the method of exponential decomposition. In addition, this study adds a variable of lag effect to the traditional model.

\[
\Delta \text{IPAT}_p = \frac{\text{IPAT}_{t+1} - \text{IPAT}_t}{\ln \text{IPAT}_{t+1} - \ln \text{IPAT}_t} \ln \left( \frac{\text{P}_{t+1}}{\text{P}_t} \right)
\]

In formula (9): the superscripts 0 and t are the base year and final year, and t and t+1 are the current year and the next year.

2.4. Description of prospects for future development

The development of the waste plastic recycling industry is a key area for a long time in the future. In this context, the prospects for the future development of waste plastics are closely related to the development of the waste plastic recycling industry. Through the description of different scenarios, the overall control and predictive analysis of the waste plastic industry can be better realized.

Scenario 1: Stable business development (BAU). It is predicted that by 2030, the annual growth rate of the plastic waste recycling industry is calculated based on the average growth rate of the past 10 years. Based on this assumption, greenhouse gas emission reductions by 2030 can be predicted.

Scenario 2: As of 2030, a total increase of 50%, that is, an annual increase of 1.56%. This prediction is based on the regulations of international government convention organizations.

Scenario 3a: As of 2030, a total increase of 70%, that is, an annual increase of 2.86%. This forecast is based on Japan's growth rate this year. As a developed country in Asia, Japan's high utilization rate of waste plastic recycling has important reference significance for my country.

Scenario 3b: Calculated based on Japan's target rate of 80%, under this scenario, China's waste plastic recycling industry will experience rapid development in 2030 and catch up with Japan's development level within 10 years.

Scenario 4a: Based on the current recycling rate of 52% of waste plastics in Western countries, under this premise, greenhouse gas emissions will be rapidly reduced in the next 10 years.

Scenario 4b: By 2030, the target growth rate is 62%, that is, an annual growth rate of 2.56%, which is the target growth rate of the European Union, the United States and Canada.

Table 1 shows the scenario analysis of the recovery rate as of 2030.

| Project          | Recovery rate(%) | Annual growth rate(%) |
|------------------|------------------|-----------------------|
| Scenario 1 (BAU) | 41               | 0.86                  |
| Scenario 2       | 50               | 1.56                  |
| Scenario 3a      | 70               | 2.86                  |
| Scenario 3b      | 80               | 3.65                  |
| Scenario 4a      | 52               | 1.65                  |
| Scenario 4b      | 62               | 2.56                  |

2.5. Data acquisition and processing

The basic data for this study comes from the China Industrial Database, which includes the relevant content and data of IPAT formula calculations and model analysis. General empirical research believes that this data is a reasonable substitute for the output of recyclable plastics and can fully measure the output of waste plastic recycling. The data is publicized every 5 years. According to the research cycle
and the data release cycle, 2013 is set as the base year. Since the country has not issued a foreign garbage ban in 2013, the impact of policy factors can also be seen as the base year. In addition, China’s plastic recycling industry has three quality standards: high-grade, intermediate-grade, and low-grade. The price standards are 7,000, 5,000, and 2,000 yuan per ton respectively, and the number of products at each level accounts for 1/3 of the total output.

3. Results and analysis
In the past 10 years, waste plastic recycling has increased from 70,000 tons in 2007 to 170,000 tons in 2018, a growth rate of more than 200%. At the same time, the Chinese government has issued a series of policies and regulations to support the waste plastic recycling industry, and government agencies have also invested a large amount of budget in the research and development department.

Using the exponential decomposition model, the specific impact of the waste plastic recycling industry on greenhouse gas emissions can be quantified. Table 2 shows the driving factors for the waste plastic recycling industry to reduce greenhouse gas emissions. From the perspective of influencing factors in the waste plastic recycling industry, these factors play a very important role in the previous formula analysis and model analysis. As can be seen from Table 2, judging by the index level, the factor of employment population has the greatest impact. The other three factors, including the scale effect, the recycling ratio, and the influence of technological factors on greenhouse gas emission reduction are not very prominent, especially the influence of technological factors on the economic effect has been in a very stable state in this decade. Although the industrial technology of the waste plastic recycling industry is developing rapidly, compared with the population scale effect brought by the accumulation of plastic waste in China, the effect of scale, recycling ratio and technological factors are relatively small.

Table 2. The driving factors for the waste plastic recycling industry to reduce greenhouse gas emissions

| Year | P (number of employees) | S (scale effect) | R (recycling ratio) | T (Technology Factor) |
|------|-------------------------|------------------|---------------------|-----------------------|
| 2007 | 1.92×10^6              | 1.40×10^-2       | 3.02×10^-1         | 1.96×10^-4           |
| 2008 | 1.92×10^6              | 1.66×10^-2       | 3.12×10^-1         | 1.96×10^-4           |
| 2009 | 1.99×10^6              | 1.98×10^-2       | 3.22×10^-1         | 1.96×10^-4           |
| 2010 | 2.12×10^6              | 2.45×10^-2       | 3.34×10^-1         | 1.96×10^-4           |
| 2011 | 2.23×10^6              | 2.73×10^-2       | 3.39×10^-1         | 1.96×10^-4           |
| 2012 | 2.34×10^6              | 3.11×10^-2       | 3.43×10^-1         | 1.96×10^-4           |
| 2013 | 2.36×10^6              | 3.20×10^-2       | 3.47×10^-1         | 1.96×10^-4           |
| 2014 | 2.42×10^6              | 3.40×10^-2       | 3.45×10^-1         | 1.96×10^-4           |
| 2015 | 2.48×10^6              | 3.65×10^-2       | 3.56×10^-1         | 1.96×10^-4           |
| 2016 | 2.56×10^6              | 3.74×10^-2       | 3.78×10^-1         | 1.96×10^-4           |

Through the above model analysis, among the five factors related to the recycling of waste plastics in my country, apart from the economic effects as independent variables, population factors, scale effects, recycling ratios, and technological factors all play different roles. As time goes by, The magnitude of its impact is constantly changing.

4. Conclusion
Compared with Western countries, China’s waste plastic recycling industry is still in its infancy, and there is still a lot of work to be done. Promote the development of waste plastic recycling industry and reduce greenhouse gas emissions from the following aspects:

(1) Research on alternative materials. The technological factor is a relatively stable influencing factor in the exponential decomposition model, and it is also a very important key point. Improve the level of technology, including optimizing the use of recycled plastics, especially high-value and high-quality plastics in waste plastics. This part of plastics is a good substitute for iron, aluminum and other metal products.
(2) Follow international standards. The redesign of packaging materials and the establishment of internationally accepted packaging design are currently internationally accepted effective recycling methods, which are very helpful to improve recycling efficiency, so it should be actively promoted in the country.

(3) Improve data support. Establish a national-level input-output database to cover the entire industrial chain of the waste plastic recycling industry. The establishment of related databases can more intuitively and scientifically reflect the development and benefit status of the waste plastic recycling industry, and accurately predict the future development prospects of the waste plastic recycling industry.

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