A Regression Analysis on the Effects of Factors on Plastic Waste Production

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Abstract. Plastic is a multi-purpose material produced in large quantities. However, the non-degradability of plastic waste also brings many negative effects. In order to solve the problem of plastic production waste, we first analyze which factors have a greater impact on the production of plastic waste, and for this reason, a multiple linear regression has been established. We quantify abstract influencing factors. After that, the data is put into Statistical Product and Service Solutions (SPSS) for processing, and the influence of different factors on plastic waste is calculated. We find that the production of plastics has the greatest impact on the increase of plastic waste, while mainland policies have the greatest impact on the reduction of plastic waste. Finally, we have a sensitivity analysis on this model to analyze the impact of various factors on the output of plastic waste.

Keywords: Plastic production waste; Multiple Linear Regression Model; Statistical Product and Service Solutions.

1. Introduction

Plastics are widely used because of their low cost, light materials, and convenience of production. However, due to its non-corrosive nature, it is difficult to dispose of, and the plastic waste flowing into the ocean alone is approximately 10 million tons every year [1], not to mention the residue in nature. Besides, plastic also poses a potential challenge to human health. To answer the question that how much plastic waste can be reduced, the degree of influence of various factors on plastic waste need to be deliberated.

At present, domestic and foreign researches on plastics mainly focuses on plastic research and qualitative analysis. Roland Geyer et al. [2] made statistics on plastic waste worldwide before 2015, and conducted detailed processing and analysis on it, roughly predicting that there will be 8300 million metric tons (Mt) of waste in 2050. produce. What’s more, Yao haowen [3] proposed a countermeasure model for the flood of plastic. Wang Jiajia et al. [4] proposed that the DPSIR model qualitatively analyzes plastic waste and its impact through driving force, pressure, state, influence and response. And Plastics Europe [5] will give a regular report on all aspects of plastics every year. Regarding the output of urban waste, although Chen Jinfa [6] once established a grey prediction model to predict the output of urban waste, he did not consider the impact of variables on the waste.

These studies are essential for us to understand plastic waste, but we still lack models or methods that can quantitatively study plastic waste based on existing data. Therefore, based on the previous research, this paper quantitatively studied the maximum carrying capacity of environmental waste and the degree of influence of various factors on plastic waste. This requires our statistics in the United Nations [7].
2. Problem Description

In order to discuss in depth, the reasons that plastic pollution affects human life, we make every effort to do the following:

We look for the influencing factors of plastic pollution and analyze the key factors that have the greatest impact on the environmental protection level. After this, we find the data of various influencing factors and analyze the weights of various influencing indicators in different regions. This requires us to build a model, analyze the data, and clarify the impact of various indicators on the environmental protection level in different regions. This will help us to formulate targeted policies in different regions. Based on the above description, the following assumptions are given:

- Assume that the capacity of plastic waste recycling in various countries and regions is constant:
- When considering environmental carrying capacity, only plastic waste is considered, and the impact of other types of waste is not considered.

In addition, we have defined some variables and explained them in Table 1. This will greatly help us in the process of building the model later.

| Variable          | Description                                      |
|-------------------|--------------------------------------------------|
| $y_1, y_2, \ldots, y_j$ | Value of non-recyclable plastic waste in j cities or regions |
| $x_1, x_2, \ldots, x_m$ | Factors affecting the value of m non-recyclable plastic waste |
| $\beta_0, \beta_1, \beta_2, \ldots, \beta_m$ | Degree of influence of m indexes ($\beta_0$ is a similar intercept parameter) |
| $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_j$ | The error value of the corresponding city or region in the calculation process |

3. Establishment of the Multiple Linear Regression Model

The maximum level of disposable plastic product waste depends on many factors. However, the main need to consider the source & current status (that is, objective factors) of the remaining plastic waste in the environment and environmental carrying capacity. When thinking about this question, we carried out variable control. Assuming that the current status and carrying capacity remain unchanged, we consider the source separately. It is known that the total amount of plastic waste remaining in the environment this year will be regarded as the current status of plastic waste in the next year, and it is the non-recyclable plastic waste that really remains and affects the environmental protection level. Therefore, in this question, we will focus on the analysis and evaluation of the value of non-recyclable plastic waste in various cities or regions.

It is known that the value of non-recyclable plastic waste in each region is a random variable $y$. In order to consider the effects of multiple non-random factors, we summarize the m factors and data of the variable $y$, and establish a Multiple Linear Regression Model to analyze the problem.

Suppose $y$ and $x_1, x_2, \ldots, x_m$ and $\beta_0, \beta_1, \ldots, \beta_m$ impact parameter has the following relationships:

$$ y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m + \varepsilon $$

(1)

At the same time, in order to accurately describe the lives of residents and the impact of national and even continent policies on the amount of non-recyclable plastic waste, we quantify the impact of these factors. Before this, we will establish an evaluation scale, which is basically divided into five items according to the importance of each influencing factor, and give evaluation values of evaluation scales
1, 3, 5, 7, and 9, and set another four scales between the five basic scales. Between the scales, and given 2, 4, 6, 8 measurement values, a total of nine scales, the significance of each scale is shown in the following Table 2:

**Table 2.** Evaluation of the impact of recycling, lifestyle, policies, and use of alternative materials

| Assessment Scale | Definition                                      |
|------------------|-------------------------------------------------|
| 1                | Condition, influence or restraint quite weak     |
| 3                | Condition, influence or restraint relatively weak|
| 5                | Condition, influence or restraint in general     |
| 7                | Condition, influence or restraint relatively strong|
| 9                | Condition, influence or restraint quite strong   |
| 2, 4, 6, 8       | Median of adjacent scales                       |

To this end, we select representative cities in the world for analysis and list the equations:

\[
\begin{align*}
y_1 &= \beta_0 + \beta_1 x_{11} + \beta_2 x_{12} + \cdots + \beta_m x_{1m} + \varepsilon_1 \\
y_2 &= \beta_0 + \beta_1 x_{21} + \beta_2 x_{22} + \cdots + \beta_m x_{2m} + \varepsilon_2 \\
&\cdots \\
y_j &= \beta_0 + \beta_1 x_{j1} + \beta_2 x_{j2} + \cdots + \beta_m x_{jm} + \varepsilon_j
\end{align*}
\]

(2)

Among them, the error terms \( \varepsilon_1, \varepsilon_2, \cdots, \varepsilon_j \) are independent of each other and satisfy the \( N(0, \sigma^2) \) distribution.

**4. Data Analysis and Results**

After establishing the model, we selected a few influential countries in the world and summarized their plastic waste residues based on data from multiple influencing factors into the following Table 3:

**Table 3.** Plastic waste and influencing factors in several cities in 2010

| Country         | Code | Year | Plastic waste generation (tonnes per year) \( w_1 \) | Source (output) \( w_2 \) | Recycle status \( w_3 \) | Use of alternative plastics \( w_4 \) | Impact on people \( w_5 \) | Continent policy \( w_6 \) | Policy \( w_7 \) |
|-----------------|------|------|-----------------------------------------------------|-------------------------|-----------------------|-------------------------------|------------------------|-------------------|-----------------|
| Australia       | AU   | 2010 | 900658                                              | 3%                      | 1                     | 8                             | 9                      | 2                 | 9               |
| Brazil          | BR   | 2010 | 11852055                                            | 11%                     | 7                     | 3                             | 8                      | 1                 | 3               |
| Canada          | CA   | 2010 | 1154309                                             | 5%                      | 6                     | 7                             | 7                      | 2                 | 6               |
| China           | CH   | 2010 | 59079741                                            | 35%                     | 4                     | 4                             | 4                      | 1                 | 3               |
| France          | FR   | 2010 | 4557128                                             | 7%                      | 1                     | 6                             | 8                      | 3                 | 9               |
| India           | IND  | 2010 | 4493080                                             | 9%                      | 5                     | 7                             | 2                      | 1                 | 9               |
| United Kingdom  | GB   | 2010 | 4925590                                             | 8%                      | 4                     | 8                             | 5                      | 3                 | 3               |
| United States   | US   | 2010 | 37825550                                            | 22%                     | 5                     | 9                             | 7                      | 2                 | 9               |

Data sources: Hannah Ritchie and Max Roser (2020) - "Plastic Pollution". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/plastic-pollution' [Online Resource]

Put the data in the Table 3 into SPSS for analysis to get Coefficients Table 4:
Table 4. Coefficients\textsuperscript{a}

| Model | Unstandardized Coefficients | Standardized Coefficients | t   | Sig. |
|-------|-----------------------------|---------------------------|-----|-----|
|       | B          | Std. Error | Beta |     |     |
| 1     | (Constant) | -19511497.659 | 1452146.563 | -13.436 | .047 |
|       | Source (output) | 2076759.465 | 21054.383 | 1.046 | 98.638 | .006 |
|       | recycle status | -261885.629 | 124032.876 | -0.027 | -2.111 | .282 |
|       | Use of alternative plastics | 993278.289 | 148123.032 | 0.966 | 6.706 | .094 |
|       | Impact on people | -1487753.375 | 389941.940 | -0.058 | -3.815 | .163 |
|       | Continent policy | -126002.615 | 101444.672 | -0.018 | -1.242 | .432 |

\textsuperscript{a} Dependent Variable: Plastic waste generation (tonnes, total) (tonnes per year)

Multivariate linear regression equation between the amount of waste remaining and the influencing factors:

\[ y = -19511497.659 + 2076759.465w_1 - 261885.629w_2 + 993278.289w_3 + 993278.289 + 1178766.689w_4 - 1487753.375w_5 - 126002.615w_6 (3) \]

From the multiple linear regression model and data analysis results, it can be known that for every 1% increase in plastic output, the global plastic waste will increase by about 2077 tonnes; for each level of recycling capacity, the global plastic waste will decrease by about 261886 tonnes; Every time the usage is reduced by one level, the global plastic waste is reduced by about 993278 tonnes; each level of residents' reaction decreases by one level, the global plastic waste is reduced by approximately 118767 tonnes; each level of stricter continent policy is increased by one level, the global plastic waste will reduce about 1487753 tonnes; for each level of stricter national policy, the global plastic waste will be reduced by about 126003 tonnes.

5. Sensitivity Analysis

Here, we perform a sensitivity analysis on the impact of the minimum level of plastic waste on human lifestyle, effects on the environment, and plastic industry.

Among them, human lifestyle can be divided into three indicators: daily necessities, everyday packaging and home appliances. Effects on the environment can be divided into three indicators: air, soil, and water, and plastic industry can be divided into raw materials, machining, detection and product sales.

Here we fill the Table 5 below with the impact of reducing plastic waste by 1000, 2000, 3000, 4000 tonnes on these ten indicators. The specific data is as follows:

Table 5. Plastic waste reduction sensitivity analysis table (Unit: tonnes)

| Index          | 1000   | 2000   | 3000   | 4000   |
|----------------|--------|--------|--------|--------|
| Daily necessities | 9.16704 | 18.33408 | 27.50112 | 36.66816 |
| Everyday packaging | 30.28094 | 60.56188 | 90.84282 | 121.12376 |
| Home appliances   | 66.65202 | 133.30404 | 199.95606 | 266.60808 |
| Air              | 37.13328 | 74.26656 | 111.39984 | 148.53312 |
| Soil             | 134.89704 | 269.79408 | 404.69112 | 539.58816 |
| Water            | 120.99132 | 241.98264 | 362.97396 | 483.96528 |
| Raw material     | 32.52640 | 65.052800 | 97.5792 | 130.1056 |
| Machining        | 179.9467 | 359.89340 | 539.8401 | 719.7868 |
| Detection        | 179.9467 | 359.89340 | 539.8401 | 719.7868 |
| Product sales    | 97.7194 | 195.43880 | 293.1582 | 390.8776 |
We found that plastic has the least impact on daily necessities and the largest impact on machining and detection.

6. Conclusions
Through Table 6 Model Summary from SPSS, we verified that the multiple linear regression equation is reasonable and effective.

| Model  | R       | R Square | Adjusted R Square | Std. Error of the Estimate |
|--------|---------|----------|-------------------|---------------------------|
| 1      | 1.000a  | 1.000    | .999              | 484201.710                |

b. Dependent Variable: Plastic waste generation (tonnes, total) (tonnes per year)

In this model summary table, R stands for goodness of fit, which is used to measure how well the model fits the known data. The closer its value is to 1, the better the model.

Table 7 shows the results of analysis of variance, which can show whether the entire regression equation has any use value.

| Model  | Sum of Squares       | df  | Mean Square     | F       | Sig.  |
|--------|----------------------|-----|-----------------|---------|-------|
| 1      | Regression           | 318227593943 | 6    | 530379323238  | 2262.215 | .016b |
|        |                      | 1462.500      |      | 577.060      |         |       |
|        | Residual             | 234451295932. | 1    | 234451295932. |         |       |
|        |                      | 576            |      | 576          |         |       |
|        | Total                | 318251039072   | 7    | 7395.000     |         |       |

a. Dependent Variable: Plastic waste generation (tonnes, total) (tonnes per year)
b. Predictors: (Constant), policy, Impact on people, Continent policy, Source (output), recycle status, use of alternative plastics

Among the above, in Table 6, R stands for goodness of fit, which is used to measure how well the model fits the known data. The closer its value is to 1, the better the model.

In Table 7, the results of the analysis of variance of the F value are used to make an overall test of our entire linear regression equation to prove whether the equation is of local use value. The Sig value corresponding to the F value is less than 0.05 can be regarded as regression Equations are useful.

The main purpose of this paper is to find the key to effectively reduce the generation of plastic waste. In order to understand how to reduce plastic waste, we first analysed the factors that affect plastic waste. We find that plastic waste is affected by plastic output, people's lifestyle, the use of recyclable plastics and policies. So, in order to minimize the amount of plastic waste in the world, not only people's efforts but also the joint assistance of governments and international organizations are needed.

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References
[1] Jenna R.Jambeck, Roland Geyer, Chris Wilcox, Theodore R. Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan, Kara Lavender Law, Plastic waste inputs from land into the ocean. Science Letter, vol 347 no.768, 2015.
[2] Roland G, Jenna R.J, Kara L.L, Production, use, and fate of all plastics ever made. Science Advances, Sci Adv vol.3 no.7, 2017.
[3] Yao haowen, Countermeasure model for the crisis of waste plastic flooding. China Resources Comprehensive Utilization, vol 38 no.6, pp69-71, 2020.
[4] Wang J.J, Liang S.Y, Liu S.L and Li Y, Analysis of Negative Impact of Waste Plastics on the Environment and Countermeasures——Based on DPSIR Model. Rural Economy and Science-Technology, vol.30 no.16, pp.1-2, 2019.
[5] Plastics-the Facts 2019, [online] Available: https://www.plasticseurope.org/en/resources/market-data.

[6] Chen J.F, Ning P, Hou M.M, Predication model for urban waste output. Recycling Research, no.6, pp 25-27, 2003.

[7] World Health Organization. SINGLE-USE-PLASTICS: United Nations Environment Programme. Nairobi: WHO, 2018.