Study on the Reduction Effect of Municipal Domestic Waste under the Fare Collection System

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Abstract: In recent years, as China's economic development and people living standards are greatly increasing, the number of waste products in a city is going extremely high. In our research, we study how the fare collection system tackles the high amount of municipal domestic wastes, and analysis how effective of the system in reducing the amount of waste production. Firstly, we decide to use MES production function to impose restrictions on four different departments of waste disposal, build up a fare collection system, which is balanced in supply and demand model for analyzing data, so as to compare the difference in the total amount of waste produced in both traditional fixed charge of waste production and the charge of classification in waste to analyze the effectiveness of reducing waste.

Keywords: MES production function; Reduction; Balance in supply and demand; Classification pricing model

1. Introduction

In September of 2017, the Central Environment Monitoring Group have started the work on environmental conservation, which shows a new stage of environmental governance in China. In recent years, many cities in China have been polluted by tons of waste. And the amount of domestic waste is in an increasing trend, which leads to lack of resources in solving the problem, so that the issue of environmental pollution has become seriously severe with each passing day. Moreover, the environmental problem is not just only affecting the Chinese sustainable development, but also becomes a devil which is damaging the China economy. According to several data, it reveals that China 18 provinces and regions' 471 county, about 400 million residents' home and land is affected by desertification, and the scale of desertification is enlarging in average more than 10000 square kilometers. Therefore, environmental governance is quite urgent.

2. The Effectiveness of Waste Reduction under Fare Collection System

According to the data provided by China Environmental Protection Bureau in 2017, we can analyze the waste into 4 different types: kitchen waste, recyclable waste, detrimental waste and other waste.

2.1. A reduction analytical model based on the balance of supply and demand

We set up a balanced function among the four departments: raw materials supplier, products manufacturer, waste sorting and recycling department, waste treatment plant.

As for function of supply, we use CSE production function:

$$z = CESx, y; \sigma = \left(x\frac{\sigma - 1}{\sigma} + y\frac{\sigma - 1}{\sigma} \right)^{\frac{\sigma}{\sigma - 1}}$$

For the raw material suppliers, the production function: Let K be the capital, 1 be the amount of labour and be the elasticity of substitution of the capital and labour.

$$Q_p = CES(k, l; \sigma^{kl})$$

For the products manufacturers, we let be the raw material, and be the recycling material and as their elasticity of substitution.

$$Q_s = \min(CES\left(k, l; \sigma^{kl}\right), CES\left(m_v, m_r; \sigma^{vr}\right)$$

For waste sorting and recycling departments, we let be the daily waste which is recyclable, be the elasticity of substitution of labour force and recyclable waste.

$$Q_c = CES(CES\left(k, l; \sigma^{kl}\right), N_r; \sigma^{klr})$$

For the waste treatment plants, we let be the kitchen waste and high moisture treatment, be waste which is normal and dry treatment and will be the elasticity of substitution of these two treatments.

$$Q_t = min(CES\left(k, l; \sigma^{kl}\right), CES(p_s, p_b; \sigma^{sb}))$$

Equilibrium models can be listed by the balance of supply and demand:

Through the amount of the production by the raw material supplier, we let be the resident used products and the amount of services, and is the usage of products and services of the department of production.

$$Q_p \geq \sum m_v$$

$$Q_s \geq \sum N_p + \sum N_s$$

The needs of recycle of waste and balance of demand and supply, we can calculate the price of recycle the material as and be the amount of recycle and utilize of waste for residents.

$$Q_c \geq \sum N_r$$

For the waste treatment plant:

$$Q_t \geq \sum N_s + \sum N_b$$

In conclusion, we can calculate that the price as kitchen waste with high moisture treatment and the price as a treatment for dry waste. Moreover, we also calculate the balance between capital and the sum of labour force.

2.2. The analysis and solution of the model of reduction

The reference value of the model will be:

σ^{kl} =0.8(refer to Draper and Manders)

$$\sigma^{vr} = \infty, \quad \sigma^{klr} = 0.125, \quad \sigma^{sb} = 0.2$$

From the above analysis, we will have the balanced model of two different types about the charge of domestic waste disposal: use as the average productivity of waste by each person, and is the amount of products used by residents.

The total amount of the productive of waste can be expressed as:

$$S_n = \sum \alpha N_i = \sum (N_r + N_s + N_b)$$

Equal Charge equilibrium:

We take M to be the fixed value of equal charges. The resident budget is constrained as follows, and are representative of capital demand, capital supply, labour demand and labour supply respectively.

$$\sum \mathrm{p}_s N_p + F = p_k k_s + p_l l_s$$

Garbage Sorting and Charging system:

The budget and limitation for residents:

$$\sum p_s N_p + \sum p_b N_l = p_k k_s + p_l l_s$$

Base on the data of relevant departments in China in 2015 (2016 China National Statistical Yearbook), the total input is 25.2 billion yuan. The gross capital income of all residents is 67.6708 trillion yuan, and the labour income is 107.7692 trillion yuan.

Table 1. The Quantity of National Economic Indicators Input in 2015

Sector Classification	Capital Input	Labour Input
Production department	170550	481481
Raw material supplier	132.86	38.50
Waste sorting and recycling department	16.06	23.10
Waste treatment department	123.64	1463

From Table 1, the budget for the national residents in 2015 is 67.43 trillion yuan. Comparing with the Equal Charge and Metered Charge, we will know the difference about the amount of domestic waste production between these two systems.

Under the mode of Equal Charge, the levy of waste disposal fee makes residents need to pay about 67.43 trillion yuan on products and services.

Referring to the Equal Charge system of many municipals, we pretend to levy 6 yuan in every month per household. According to China National Statistical Yearbook, we know that there are 160 million urban residents in China, and the estimated rate of charge will be 70%. Therefore, the annual charge which levied from domestic waste treatment will be 4.319 billion yuan.

Under the mode of Metered Charge, the residents have to pay the corresponding handling expenses for each additional unit of domestic waste. Therefore, it can improve the reduction of domestic waste.

The above model of and represent the charge rate of waste of sanitary heavy water treatment and the charge rate of dry garbage treatment. Domestic waste disposal should be classified and charged at different rates for different types, so that residents can reduce the production of high-cost garbage and is conducive to the reduction of domestic garbage.

In conclusion, we can see the effectiveness of the Metered Charge system for domestic waste disposal is better than that of the Equal Charge system. Moreover, if the Metered Change system will implement on the classification of domestic waste, it will achieve a better effect of reduction.

3. Cross-validation of the Reduction Model

The relationship between the sorted waste charge and reduction is analyzed using 2013 Shenzhen Community data for verification and analysis. (See Appendix for data.)

Table 2. Source Waste Components

Items	Percentage composition(%)	Moisture content(%)	Dry matter content (g/100g wet waste)	Dry base high calorific value(kJ/kg)

Kitchen garbage	65.54	73.22	17.55	14400
Paper	6.82	11.83	6.01	16600
Plastic	12.75	4.00	12.24	32570
Textile	4.16	9.50	3.76	17450
Wood & Bamboo	1.21	10.00	1.09	18610
Brick	2.07	10.86	1.84	6980
Glass	1.86	0.68	1.85	140
Metal	0.53	4.00	0.51	700
Others	0.10	0.00	0.10	0
Orthod	4.97	15.00	4.22	6980
Grand total	100	50.83	49.17	6931

First, quantify the classified index of garbage classification. Combining the reality and policy, the classification of domestic waste can be divided into garbage with high water content, and recyclable waste. The hazardous waste has the uncertainty, and occupies relatively small, so it can be neglected in the classification.

The classification index:

$$T_{\text{classification}} = 1 - (|a_w - A_w| + |a_g - A_g|)$$

In the formula, a_w, A_w, represent the actual classification proportion of waste with high water content and the proportion of source waste respectively. And a_g, A_g represent the actual classification proportion of dry waste and the proportion of source waste respectively.

The total amount of waste is normalized, and the waste reduction index is expressed by the normalized data:

$$T_{waste\ reduction} = \frac{S_i - min(s)}{max(s) - min(s)}$$

The relationship between the index of classification and the index of waste reduction.

Linear regression analysis of $T_{\text{classification}}$ and $T_{waste\ reduction}$:

The model is positively correlated, which indicates that the Waste Classification Charge System has a positive effect on the total waste reduction. And the above conclusions of the model can be verified through practical cases.

Since 2001, Japan has widely implemented the domestic waste charge system on the basis of classification, and the effect of reduction is significant.

Since the implementation of domestic Waste Classification Charge system in Taiwan area, the production of household garbage in Taipei has decreased to two-thirds, and the resource recovery rate has risen to 3 times of the original.

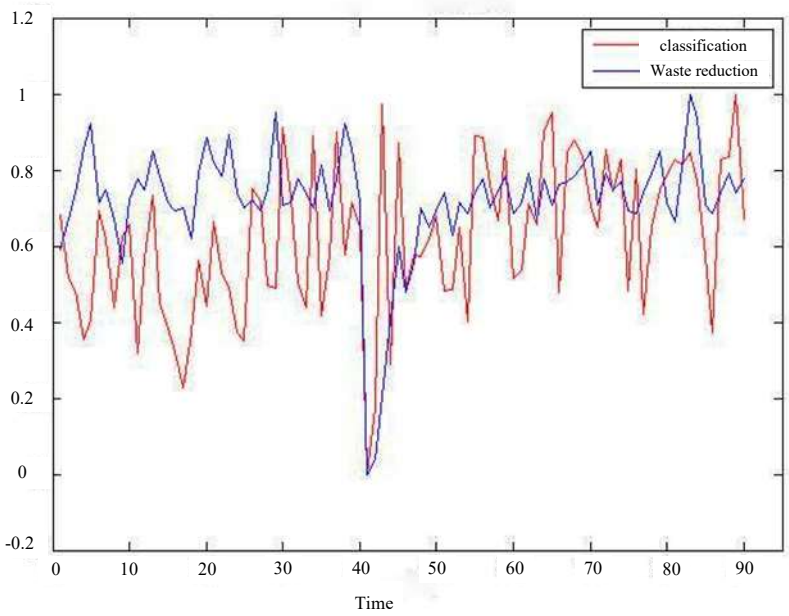

Figure 1. The analysis of two indicators in Community1

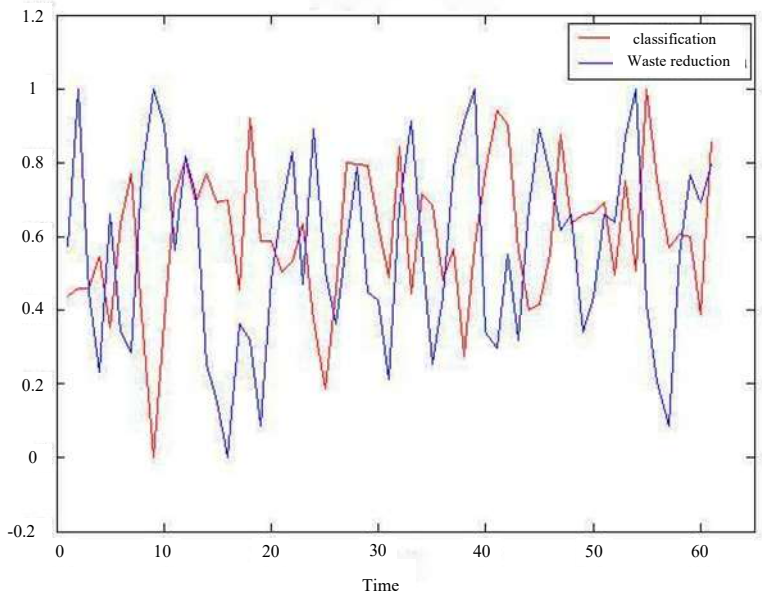

Figure 2. The analysis of two indicators in Community2

Table 2. The Result of Community1 and Community2

Community 1			Community 2		
Regression Coefficient	TSS	Correlation Coefficient	Regression Coefficient	TSS	Correlation Coefficient
0.8820	3.7046	0.87	0.8049	3.0012	0.78

4. Model Evaluation

The cost indexes in the social cost accounting model quoted in this paper are specific and diverse, so they are more universal, adaptable and applied.

Different treatment methods have their corresponding cost accounting items, which can be better applied to other waste disposal modes besides the five modes in this paper. As for the Supply Balance model, it is innovative and has social value and accuracy from the economic point of view. On the basis of the research, the total social cost can be accounted for only by selecting the cost items correspondingly according to the steps in the treatment mode and the corresponding methods.

5. Conclusion

In this paper, MES production function is selected to establish the Supply and Demand Balance model. The total amount of waste under the charge system is calculated quantitatively, and analyzed its effect of reduction by using the model. What's more, we use the data of a residential area in Shenzhen to verify the rationality and scientificity of the model. It provides a reference for future research on waste reduction under the charge system.

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References

[1] Lu Baozhi, Ma Huafeng. Government allowance measurement of waste treatment projects under various investors.Environmental Sanitation Engineering. 2014, 22, 45-47.

[2] Hu Jianwen, Yang Kai, Wang Hui, Che Yue. Charging system of domestic waste treatment at home and abroad and its application in shanghai. Environmental Sanitation Engineering. 2013, 21, 15-18.

[3] Liu Jingyuan, Xu Haiyun. Discussion on Sorted collection and charging method of municipal urban waste in china. Environmental Sanitation Engineering. 2004, 12, 23-27.