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Municipal household solid waste fee based on an increasing block pricing model in Beijing, China

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Abstract

This article aims to design an increasing block pricing model to estimate the waste fee with the consideration of the goals and principles of municipal household solid waste pricing. The increasing block pricing model is based on the main consideration of the per capita disposable income of urban residents, household consumption expenditure, production rate of waste disposal industry, and inflation rate. The empirical analysis is based on survey data of 5000 households in Beijing, China. The results indicate that the current uniform price of waste disposal is set too high for low-income people, and waste fees to the household disposable income or total household spending ratio are too low for the medium- and high-income families. An increasing block pricing model can prevent this kind of situation, and not only solve the problem of lack of funds, but also enhance the residents' awareness of environmental protection. A comparative study based on the grey system model is made by having a preliminary forecast for the waste emissions reduction effect of the pay-as-you-throw programme in the next 5 years of Beijing, China. The results show that the effect of the pay-as-you-throw programme is not only to promote the energy conservation and emissions reduction, but also giving a further improvement of the environmental quality.

Keywords

Municipal household solid waste, fee, block pricing, validity, equity

Introduction

Since the early 1990s, many governments in developing countries have become increasingly concerned with municipal household solid waste (MHSW). Urbanisation, population growth, and industrialisation are three key reasons behind the large magnitude of China's increase in total waste generation (Zhang et al., 2010). For example, the collection and transportation amount of MHSW in China has amounted to 164m t, tonne (t) = 1000 kg or 2204.6 lb (instead of ton = 1016.05 kg or 2240 lb UK (907 kg or 2000 lb US)) – please confirm units or re-calculate as necessary – please check throughout the article.]and the quantity of innocuity disposal of it has reached 131m t, whereas the hazard-free treatment rate of it only reached 79.88% in 2012. It is estimated that Chinese cities produce nearly 200m t of waste per year, and that the amount is still increasing year by year, with a growth rate of about 10%; nearly two-thirds of Chinese cities have been tightly encircled by waste (Hou and Ma, 2005). Generation of MSHW is far faster than the self-purification ability of the environment and governance capacity of the existing waste disposal facilities.

Communities from developed countries (such as the United States, South Korea, Japan, Switzerland, and Belgium) charge residents a fee for each bag or can of waste. Such fees are normally based on the pay-as-you-throw (PAYT) programme. PAYT is becoming widely applied in pricing systems of municipal solid waste, the main purpose being to support sustainability – from economic, environmental, and social points of view (Elia et al., 2015). Therefore, the economic burden of the waste fee is comparatively fair, and leads to a significant improvement in the environmental awareness of the residents, thus promoting waste reduction. 'Waste reduction' refers to the avoidance of waste generation incentivised by appropriate charging of the residents. According to a Singapore experiences, the PAYT programme could bring a 73% waste reduction (Zhu, 2006). Since 1995, South Korea charges residents a waste fee based on a PAYT programme, and has a outstanding municipal solid waste recycling performance (Park and Lah, 2015). Kulas analysed the waste reduction data of 32 towns in Connecticut and found that there is

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a negative relationship between municipal solid waste levels and PAYT pricing (Kulas, 2015). But most cities of China rarely charge the residents with the PAYT programme; most of them use the ration charge mode to charge the waste fee. The corresponding waste reduction effect is relatively weak because of: (a) the lack of waste disposal facilities, and the existing low-level processing facilities; and (b) the nation's growing waste output. A natural way of solving the not-in-my-back-yard problem is to apply a price to the disposal of waste (Sakai, 2012). Charging a MHSW fee could not only compensate the government and investment of the enterprises, but also actively promote the reduction and recycling use of domestic waste (Dunne, 2004; Jiang, 2001). That proportion of the costs not covered by the proceeds of treating the waste must be defrayed in accordance with the 'polluter pays' principle (Dunne et al., 2008).

For reducing waste and implementing the polluter pays principle, achieving the internalisation of external costs, and also compensating cost of the disposal processes, scientific and reasonable formulation of MHSW fee standards is imperative.

The municipal solid waste pricing method should internalise the social costs of municipal solid waste and balance the transaction costs (Menell, 1990). The unit price should be set equal to marginal costs of waste disposal to achieve economic efficiency (Miranda, 1994). Communities that have adopted some form of unit pricing usually turn to average cost pricing or two-tier pricing. The impact of price incentives under the unit pricing system on municipal solid waste generation make the marginal cost as the basis of municipal solid waste fee pricing (Hong, 1999). Full-cost accounting is a useful tool to calculate the cost of waste services, basic waste fees can be calculated by fixed costs/variable costs, direct/indirect costs, and controllable cost/uncontrollable cost (Hogg, 2002). Sakai mentions that PAYT charging systems can be roughly divided into two groups – simple unit-pricing systems and flat-fee systems (Sakai et al., 2008) – but Suzuki and Rahardyan show that the primary reason for introducing a charging system is waste reduction, and flat-fee systems do not contribute to waste reduction, so flat-fee systems should not be considered in PAYT systems (Suzuki, 2005; Rahardyan et al., 1994).

Increasing block pricing is seen as one way to ensure that nearly every household can afford a basic quantity of demand, while raising additional revenue from wealthier consumers (Borenstein, 2012). Because low-income individuals have less disposable income, waste collection fees represent a greater proportionate burden on them than on high-income households, increasing block pricing systems is built-in protection for poor families (Bauer and Miranda, 1996). It is also a fair system as people are billed according to what they produce (OECD, 2004). Evolution from unified price setting to increasing block pricing could achieve both goals – prevent from increasing the cost of vulnerable groups and reduce the aggregate demand. Structural analysis (Hewitt and Hanemann, 1995; Pint, 1999) and meta-analysis (Dalhuisen and Nijkamp, 2003; Espey et al., 1997) verified that the consumer price elasticity under the increasing block pricing is bigger than linear marginal pricing.

The pricing method of increasing block pricing is such that within the scope of a certain amount of solid waste, the resident will bear the expenses of a small percentage of definite appropriation, and once higher than the certain standard, the resident will bear higher expenses (He, 2013; Yin, 2007). Increasing block pricing is widely used in most of the cities in Japan. According to the Japanese experiences, the increasing block pricing mode can bring a high level of waste reduction. Comparing 1999 to 2005, there has been a reduction of non-combustible rubbish and combustible rubbish in Japan of at least 50% and 44% (Hu et al., 2013).

This article aims to contribute towards that end by designing the increasing block pricing model of MHSW in Beijing, China. This kind of pricing method ties the pricing of waste disposal more closely to the actual waste emissions of the residents. Thus, the residents will gradually change their spending habits to reduce the expenses of waste fees, which is bringing a very significant effect of waste reduction and recycling, green purchasing, and sustainable development. The rest of this article is organised as follows: The following section introduces the status quo of the MHSW generation and charging system of Beijing in recent years, and then describes the modelling methodology of the increasing block pricing that we employ in our analysis and presents the results obtained by a case study of Beijing, China, in 2012. 'Comparative study' provides a comparative study on the waste reduction effect between increasing block pricing mode and the existing pricing mode of Beijing. The final section provides conclusions.

Materials and methods

Study area

Beijing is the capital of the People's Republic of China, situated in northern China, close to the port city of Tianjin and partially surrounded by Hebei Province, located in 39° north latitude 54 points, longitude 116° 23 points. In 2012, Beijing had an estimated urban population of 17.84 million, and covered an area of 12,187 km^2. Beijing serves as an important political, economic, cultural, educational, and international trade and communication centre of China.

In 1991, China put forward a corresponding policy on the charging of waste disposal service. In 1993, the scope of the payment group had gradually extended to the resident. In September 1999, Beijing started to impose fees for municipal solid waste in quota charges. And in 2009, Beijing began to try a PAYT programme that was tested in the Chaoyang District Wheat Community and Haidian District Xintai Mansion. The PAYT programme that is starting to be implemented is a two-way weighing and charging waste fee with each litre of water, and Beijing is beginning to study the new charging mode of municipal solid waste disposal fees for waste management now.

Generally, the greater the economic prosperity and higher the percentage of urban population, the larger the amount of solid waste produced (Hassan, 2000). Between 2005 and 2012, the quantity of municipal solid waste collected and transported increased continually in Beijing (Figure 1). In 2012, the daily average municipal solid waste generation in Beijing was 17,760 t, or 0.996 kg per capita (Table 1).

The results from Jenkins' statistical analysis of waste emissions of 14 foreign countries indicate that the price elasticity of MHSW emissions demand is −0.12 (Jenkins, 1993); that is, a 1% increase in waste fees causes a 0.12% decrease in MHSW generation. The low-price elasticity and waste reduction rate means that the current charging system of MHSW has little effect on waste reduction in Beijing (Table 1). In Beijing, every household just pays 3 RMB yuan (or about 46 cents US$) a month, which is not enough to support the whole process of waste separation and treatment, and increases the economic burden of the government.

Through the survey we found that the population of each household remains relatively stable for a long time, with an average of three people in each household. Therefore, the MHSW emission is mainly affected by income, and keeps an approximate direct ratio in relation with income. But according to the historical data, waste fee to income ratio is too low to make a psychological effect of MHSW emission reduction in Beijing (Table 2). Considering the acceptability of low-income households, we set the waste disposal unit price of the first ladder accounts income of low-income households for 2%, and according to the actual situation can be increased year by year.

Figure 2 shows the variation in the productivity change in the waste disposal industry and inflation rate from 2002 to 2012.

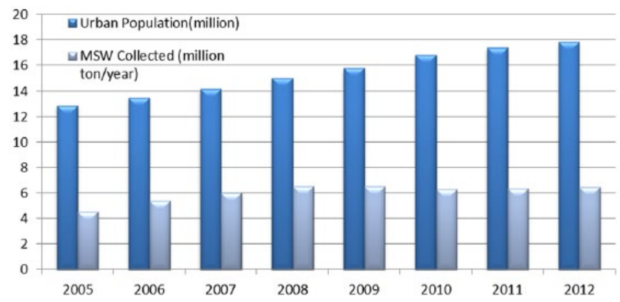

Figure 1. Variation of quantity of municipal solid waste between 2005 and 2012.MSW: municipal solid waste.

Data collection

The purpose of the statistical survey is getting accurate data to reflect the objective reality, however, no matter what kinds of data collection and research methods are used, a certain degree of error will still occur, therefore we used process standardisation to reduce these errors as far as possible. The data underlying this study was collected from the Beijing Statistical Yearbook (2013).

Table 1 shows the per capita quantity of MHSW of Beijing, from 2005 to 2012. Table 2 contains parameters including per capita income, the per capita quantity of the MHSW, as well as calculated data such as the waste fee to income ratio and per capita waste fee of MHSW.

The proportion being selected as samples and the income range of each income standard are both according to the National Bureau of Statistics of China. Among the representative sample of 5000 households, there are 1000 low-income households, 3000 middle-income households, and 1000 high-income households. In

Table 1. Per capita quantity of MHSW (t y^{-1} $person^{-1}$), 2005 to 2012.

Year	Urban population (×10^4)	Quantity of MHSW collected per year (×10^4 t)	Per capita quantity of MHSW (t y^{-1} $person^{-1}$)	Increasing rate of Per capita quantity of MHSW
2005	1286	454.6	0.3535	0.1278
2006	1350	538.2	0.3987	0.0645
2007	1416	600.94	0.4244	0.0645
2008	1504	656.61	0.4366	0.0287
2009	1581	656.12	0.4150	−0.0494
2010	1686	632.98	0.3754	−0.0953
2011	1740	634.35	0.3646	−0.0289
2012	1784	648.31	0.3635	−0.0031

MHSW: municipal household solid waste.

Table 2. Waste fee to income ratio of low-income households, Beijing.

Year	Per capita income (RMB)	Per capita quantity of MHSW (t m^{-1} $person^{-1}$)	Waste fee to income ratio (%)	Per capita waste fee of MHSW (RMB $month^{-1}$ $person^{-1}$)
2009	410	0.0346	0.70	2.8646
2010	430	0.0313	0.65	2.7822
2011	480	0.0304	0.57	2.7595
2012	520	0.0303	0.53	2.7571
Average	460	0.0316	0.61	2.7908

MHSW: municipal household solid waste; RMB: renminbi yuan.

2012, the income distribution and average family size of each income level of households in Beijing was summarised in Table 3. And Table 4 shows the per capita disposal income (PCDI) and consumption expenditure (PCCE) of Beijing in 2012.

Modelling

We divided the emissions of MHSW by weight into three ladders: At the first ladder, the range of waste emissions is from 0 to Q_A, and the corresponding fee standard is P_A. The waste emissions level of this ladder should ensure that the essential discharge demand for a low-income family is satisfied, and the price should be affordable to not create a life burden. Life burden mainly includes two aspects: The psychological burden and the economic burden. The value of Q_A could be determined by the average waste emissions of a low-income family; at the second ladder, the range of waste emissions is from Q_A to Q_B, and the corresponding fee standards is P_B; at the final ladder, the range of waste emissions is greater than Q_B, and the corresponding fee standards is P_C. The waste emissions level of the second and third ladder should ensure that the essential discharge demand of medium- and high-income families is satisfied. The value of Q_B could be determined by the average waste emissions of a medium-income family. Therefore, we reason that: Actual waste emissions of the first ladder Q should be $0 \leqslant Q < Q_A$; actual waste emissions of the second ladder Q should be $Q_A \leqslant Q < Q_B$; actual waste emissions of the second ladder Q should be $Q_B \leqslant Q$, and $P_A < P_B < P_C$.

The increasing block pricing model of MHSW is:

$$R(Q)=\begin{cases} P_A Q & 0\leqslant Q\leqslant Q_A \\ P_A Q_A + P_B\left(Q_B - Q_A\right) & Q_A\leqslant Q\leqslant Q_B \\ P_A Q_A + P_B\left(Q_B - Q_A\right) + P_C\left(Q - Q_B\right) & Q_B\leqslant Q \end{cases} \quad (1)$$

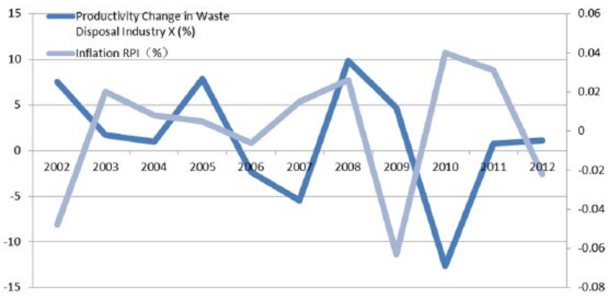

Figure 2. Variation of productivity change (X) and inflation Retail price index (RPI), Beijing, 2002 to 2012.

This model is based on the PAYT principle, so the waste collection system mainly include two modes: Charge residents a waste fee for each bag or each can of waste. Considering the reality condition of China and the policy costs, all of the waste emission-related variables in this model are measured and collected by bags.

The analysis of this article is based on the hypotheses as follows.

Hypothesis 1: Supply–demand relationship of MHSW maintains a relatively stable state for a certain period.

Hypothesis 2: The amount of MHSW generation equals the MSHW collection.

Hypothesis 3: Combining the Beijing statistical yearbook with the questionnaire results, we found that the average number of people per household in Beijing is about three, so MSHW emissions standards in the formula is the average waste emissions of these three.

Under the above three hypotheses, the economic analysis was performed using equations (2)–(9) as follows (Chen and Liang, 2002; Littlechild et al., 1983).

$$Q_A = 0.2285\ln\left(M_L\right) - 0.2821 \quad (2)$$

where M_L is the per capita disposable income of the low-income family:

$$Q_B = 0.2285\ln\left(M_M\right) - 0.2821 \quad (3)$$

where M_M is the per capita disposable income of the middle-income family.

When calculating the value of the variable P_A, first we assume that π is the profit of the waste removal company, $C(G,r)$ is the waste disposal expenses as a function of waste generation G and recycling rate r; $R(\mathrm{G,r,P}_g)$ is the value of waste recycling as a function of waste generation G, recycling rate r and the market price of recycling products P_g. In summary, we have:

$$\pi = PG + R\left(G,r,P_g\right) - C\left(G,r\right)$$

Using the Lagrange method to solve profit maximisation, we have:

$$\frac{\partial \pi}{\partial G} = P + \frac{\partial R(G,r,P_g)}{\partial G} - \frac{\partial C(G,r)}{\partial G} = 0$$

Table 3. Income distribution of Beijing, 2012.

	Average incomes in the city (RMB)	Low-income households (20%) (RMB)	Middle-income households (60%) (RMB)	High-income households (20%) (RMB)
Average gross annual family income (RMB)	41,103	18,824	27,986	74,096
Average family size (person)	2.7	3.1	2.8	2.4

Table 4. PCDI and PCCE in Beijing, 2012.

Year	PCDI (RMB)	PCCE (RMB)
2012	36,468.80	24,045.90

Table 5. Waste disposal fee and recycling value.

Year	Waste disposal fee (RMB)	Recycling value (RMB)
2006	42,552	4053.1
2007	43,290	3804
2008	34,517	5841
2009	40,090	1176
2010	41,769	325

Therefore, we have:

$$P_A = \frac{\partial C(G,r)}{\partial G} - \frac{\partial R(G,r,P_g)}{\partial G} \quad (4)$$

$$P_B = P_A \times (1 + K_M) \quad (5)$$

where:

$$K_M = \frac{(I_M - I_L)}{I_L} \times 100\%$$

M is the population of the middle-income family; K_M is the rate of income gap between the middle-income family and low-income family; I_M is the average income level of the middle-income family; and I_L is the average income level of the low-income family.

$$P_C = P_B \times (1 + K_H) \quad (6)$$

with

$$K_H = \frac{(I_H - I_M)}{I_M} \times 100\% \quad (7)$$

where H is the population of the high-income family; K_H is the rate of income gap between middle-income family and high-income family; I_H is the average income level of the high-income family; and I_M is the average income level of the middle-income family.

We used the price cap regulation model (Littlechild, 1983) to adjust the waste disposal unit price of each ladder:

$$P'_A = P_A \times (1 + LPI) = P_A \times (1 + RPI - X) \quad (8)$$

$$P'_B = P_B \times (1 + LPI) = P_B \times (1 + RPI - X) \quad (9)$$

where P_A is the waste disposal unit price of the first ladder in the base period; P_B is the waste disposal unit price of the second ladder in the base period; P_A' is the waste disposal unit price of the first ladder in the current period; P_B' is the waste disposal unit price of the second ladder in the current period; *LPI* is the limit of price increase; *RPI* is inflation rate; and *X* is the percentage of the industry productivity change in a certain period of time that set by the government.

According to Table 3, we know that in 2012, the per capita disposable income of the low-income family (M_L) of Beijing = Average gross annual family income ÷ Average family size ÷ 12 months = 18,824÷3.1÷12≈506.02 yuan $month^{-1}$. In a similar way, the per capita disposable income of the middle-income family (M_M) of Beijing = 27,986÷2.8÷12 ≈ 832.92 yuan $month^{-1}$. Putting this data into equations (2) and (3), the calculation results are shown as:

Q_A = 0.2285ln(506.02)-0.2821≈1.1407 t $month^{-1}$ $capita^{-1}$

Q_B = 0.2285ln(832.92)-0.2821≈1.2545 t $month^{-1}$ $capita^{-1}$

According to Table 3, we also can find that: K_M = (I_M-I_L)÷I_L×100% = (832.92–506.02)÷506.02 = 64.6%. In a similar way, K_H(I_H-I_M)÷I_M×100% = 2.09.

Put K_M, K_H, and the data of Tables 4 and 5 into equations (4)–(7), we can calculate the P_A, P_B, and P_C:

P_A = 63.23 yuan t^{-1};

P_B = 104.08 yuan t^{-1};

P_C = 321.61 yuan t^{-1}.

and then, putting the value of P_A and P_B into equations (8) and (9), we get the waste disposal unit price of the each ladder:

P_A' = 64.19 yuan t^{-1};

P_B' = 105.66 yuan t^{-1};

P_C' = 326.49 yuan t^{-1}.

Results

The calculated results for increasing the fee of the block pricing scheme for waste in the year 2012 for Beijing are shown in Table 6. The waste emissions of the first ladder are to meet the demand of low-income households' basic living needs; and such an emission level is independent of the price. Therefore, P_A is made to consider the welfare. The waste emissions of the second ladder is mainly used for improving and promoting the living standards of urban residents, so the P_B is acceptable for most of the urban residents. However, the waste emissions of the third ladder, which are more than the normal amount of emission demand, belongs to the category of excessive emissions, so P_C is made to consider the punishment charges.

In the process of calculation, we found that the per capita generation of MSHW of low-income households is less than either the middle-income households or the high-income households, but the per capita generation of MSHW of middle-income households is more than the high-income households. It means that generation of MSHW is not only increased with the improvement of income, it may be mainly because of the frequent eating-out of the high-income households.

Table 6. Increasing block pricing scheme of waste fee in Beijing, 2012.

Range of per capita generation of MSHW (t $month^{-1}$ $person^{-1}$)	The unit price of each ladder (RMB t^{-1})
0–1.1407	63.23
1.1407–1.2545	104.08
Above 1.2545	321.61

Table 7. Adjusted increasing block pricing scheme of waste fee in Beijing, 2013.

Range of per capita generation of MSHW (t $month^{-1}$ $person^{-1}$)	The unit price of each ladder (RMB t^{-1})
0–1.1407	64.19
1.1407–1.2545	105.66
Above 1.2545	326.49

We compared the unit price of each ladder with the current market price and found that: P_A was less than the current market price, it indicated that the current waste fee is priced without considering the acceptability of low-income households, our country should take an increasing block pricing mechanism of MHSW, and take price subsidies to vulnerable groups for protecting their rights of reasonable waste discharge; P_B was more than the current market price, it shows that the circumstances of low waste fee is prominent, and waste fee to the PCDI or PCCE ratio is too low. This leads to the low psychological effect of energy saving and emission reduction. In addition to that, the low waste collection fee also leads to the long-term loss of the waste disposal enterprises.

We used a price cap regulation, which is mainly used in the public utility industries in the UK and US to adjust the unit price of each ladder by the productivity change in the waste disposal industry (X) and the inflation rate (RPI) of the base period. The results show that the current period price of each ladder has a stable trend of increasing (Table 7). It also means that along with the socio-economic development and the improvement of living standards, the unit price of each ladder can be increased appropriately year by year.

Comparative study

A PAYT programme for municipal solid waste services has been studied (He, 2004). According to the data collected from 14 cities abroad for several years, Jenkins calculated the price elasticity of the demand of waste emissions to be 0.12 (Jenkins, 1993). This shows that, as the living garbage increases by 1%, the emissions of the solid waste will have a 12% reduction. It can be seen that the reduction effect of the waste emissions is not obvious, because the waste emissions of the resident is inelastic. But this is not the case in China, the cardinal number of waste emission of China is big. We lack the parameters of the waste reduction, so we used some of the data from the literature to form a preliminary forecast for the waste emissions reduction effect of the PAYT programme for the next 5 years of Beijing, China. Table 8 is the data of the waste emissions in 2004–2013.

Table 8. Waste emissions of Beijing, 2004–2013.

Year	Collected municipal solid waste (10,000 t)	Year	Collected municipal solid waste (10,000 t)
2004	491.00	2009	656.12
2005	454.60	2010	632.98
2006	538.20	2011	634.35
2007	600.94	2012	648.31
2008	656.61	2013	671.69

Table 9. The simulation results of the GM (1,1) model of waste emissions in Beijing, China.

Year	Value of simulation	Actual value	Residual error	Relative error (%)
2004	491.00	491.00	0	0
2005	534.6125	454.60	80.0125	17.6006
2006	552.1928	538.20	13.9928	2.5999
2007	570.3513	600.94	−30.5887	−5.0901
2008	589.1069	656.61	−67.5031	−10.2805
2009	608.4793	656.12	−47.6407	−7.2610
2010	628.4887	632.98	−4.4913	−0.7096
2011	649.1561	634.35	14.8061	2.3341
2012	670.5031	648.31	22.1931	3.4232
2013	692.5521	671.69	20.8621	3.1059

According to the modelling steps of the grey model, and using the data of waste emissions of Beijing (Table 8), we built the GM (1,1) forecasting model, as below (equation (10)), to forecast the amount of the waste emissions:

$$\widehat{X}k+1=16257.383629e^{0.032355k}-15766.383629 \tag{10}$$

and

$$\widehat{X}^{(0)}(k)=\widehat{X}(k+1)-\widehat{X}(k),$$

among that

$$\widehat{X}^{(1)}(1)=\widehat{X}^{(0)}(1).$$

The calculation results are shown in Table 9.

By analysing the simulation results, we found that the relative error of the actual value and the simulation value of the waste emissions of Beijing (from 2004 to 2013) is small, most of them are less than 10%. This is the effect of the execution of the unit pricing policy of the municipal solid waste in Beijing; it makes the modelling error smaller (Yang, 2009).

Using a posteriori test for further calculation, we could find that: c = 0.65<0.8(c=s2/s1=41.53534/63.47159=0.65), $p=P(|\varepsilon(k)-\bar{\varepsilon}\rangle\langle 0.6745S_1=42.8116)=1\rangle 0.6$, the model is basically qualified, and it can be used for simulated prediction. The simulation result is shown in Table 10.

The results show that, under no external uncertainty circumstances, like the change of policy, the municipal solid waste

Table 10. Prediction of the waste emissions of Beijing, 2016–2021.

Year	Prediction of the waste emissions (10,000 t)	Year	Prediction of the waste emissions (10,000 t)
2016	763.1457	2019	840.9351
2017	788.2412	2020	868.5887
2018	814.1620	2021	897.1516

Table 11. Predicting outcomes of the reduction of waste emissions of Beijing, 2016–2021.

Year	Prediction of the waste emissions (10,000 t)	Prediction of the reduction of the waste emissions (10,000 t)
2016	763.1457	92.8223
2017	788.2412	95.6170
2018	814.1620	98.5035
2019	840.9351	101.4849
2020	868.5887	104.5644
2021	897.1516	107.7452

emissions of Beijing will be increased year by year. The predicting result shows that by 2021, the amount of the waste emission of Beijing will rise up to 8.97151614m t.

After predicting the waste emissions of Beijing in the next several years, at the basis of the elastic parameter researched by the Jenkins (1993), we can know that the predicted price change is about 1%. Table 11 shows the predicted outcomes of the reduction of the municipal solid waste emissions of Beijing, from 2016 to 2021.

According to the Table 11, it can be seen that for the next few years, if Beijing carries out the pricing policy of the PAYT programme, the waste emissions of the Beijing for the next few year will have a reduction of at least 0.9m t. The effect of the PAYT programme is not only the reduction of the waste emissions, but also giving a further improvement of the environmental quality of Beijing.

Discussion and conclusion

Increasing block pricing in solid waste fees could not only reduce the burden of low-income families, but also increase the spending of the excessive waste discharge families advocating for justice, and the price level shall be acceptable and binding upon them.

On the basis of making a consideration on the difference of disposable income between residents at all levels, we established an increasing block pricing model of MHSW, and according to the current productivity change in the waste disposal industry and inflation, revised the price of each ladder in the base period. Case studies of Beijing, China, calculated each ladder of waste disposal unit price in 2012 and the current charging standard of the MHSW fees in decreasing order: Waste disposal unit price of the third ladder > waste disposal unit price of the second ladder > current market price > waste disposal unit price of the first ladder. This fully shows that the current uniform price of waste disposal is set too high for low-income people without considering their acceptability, and moreover, waste fees accounted for the proportion of household disposable income or total household spending is too low for the medium- and high-income families. This led to a little energy conservation and emissions reduction effect.

This study established a prediction model to forecast and evaluate the implementation effect of the increasing block pricing mode in Beijing. According to the comparative study between the increasing block pricing mode and the existing pricing mode of the Beijing-Ration Charge Mode, we found that considering the environmental effect, the increasing block pricing mode is more effective, and can not only bring a high level of waste reduction, but also improve the environmental quality. In conclusion, the increasing block pricing mode is overall feasible in China, and about the specific details and standards, it is supposed to follow the method of public policy decision-making. The study is still in the preliminary trial stage, it remains to be improved in many ways.

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