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Using a choice experiment to select the basket of improving the air quality in Chongqing, China

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Abstract: Air quality has a significant relationship with our life. Residents are concerned with the environment issue of Chongqing, which used to be one of major industrial cities in China. We choose the air quality of Chongqing as the research object, valued by choice experiment model with designed questionnaires, to discuss the best approach of improving the air quality. Firstly, the paper introduces the representative methods of the stated preferences: CVM and choice experiment (CE). The choice experiment (CE) could be designed in a series of situations with many different attributes to test the relative values among the attributes, which are the evidences of ranking importance of the attributes. Because the improvement of air quality is affected by multiple factors, the technique is better at valuing the economical impacts. Once the attributes and levels are decided, profiles and choice sets can be designed. We can also collect data through questionnaires and use the conditional logit model to evaluate the improvement of air quality in Chongqing.

The result shows the relative importance of the elements selected to evaluate the improvement of urban air quality. In a word, this research has important practical value to better the air quality.

Keywords: choice experiment; Chongqing; air quality; value evaluation; conditional logit model

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1 Introduction

Air quality, as one of the hottest topics in the world, has a significant relationship with the individual’s health and life. And air pollution has been recognized as a threat to human health as well as to the earth’s ecosystems. According to the 2014 WHO report, air pollution in 2012 caused the deaths of around 7 million people worldwide (1). The paper is to show that the correlation between five attributes and their effects on air quality. The choice experiment, an extensional contingent valuation, is the major valuation method to analysis the data collected from our questionnaires. Meanwhile, the social welfare method is also used in this research to estimate the impacts of the attributes on other aspects.

2 Choice experiments

The CE and the CVM are the representative methods
of the stated preferences \(^2\). The initial choice experiment (CE) can date back to Louviere \(^3\) and Hensher’s \(^4\) research into the market and transportation.

Compared with the CVM applying only one variable to estimate the economic value of resources, the CE method could be designed in a series of situations with many different attributes to test the relative values among the attributes, which are the evidences of ranking importance of the attributes. In fact, the public choices of improving the urban air quality are decided by multiple environmental elements. Thus, the CE method is more suitable for our program.

The CE method has several advantages in survey and analysis. In the CE method, respondents need face the choice sets, including some alternative scenarios, to select the optimal one in the What-if scenarios. At the same time, direct survey evidence on individuals’ stated valuations for non-market goods (such as public goods, and health effects) elicits the individual’s willingness-to-pay indirectly. In addition, CE method can provide evidence on both use values and non-use values, depending on the design.

Despite these advantages of CE, there are very few examples using it to estimate the value of measures of improving regional air quality. Hence, we report a study on estimating the best basket to improve the air quality in Chongqing, China.

To sum up, the steps of CE method are as follows.


Step 2. Attribute selection: decide on the number of attributes and define their nature.

Step 3. Assignment of attribute levels: assign values to all attributes.

Step 4. Determination of experimental design: construct the choice tasks, alternatives or profiles that will be presented to the respondents.

Step 5. Sample sizing and data collection: refer to data collection costs.


Step 7. Interpretation/Policy Analysis/decision support system: generate welfare estimates/predictions of behaviours, if appropriate.

3 An air quality improving program: a case study

Chongqing, located in the southwest of China, is one of China’s four municipalities directly under the Central Government. It used to be one of the most important industrial cities in China. After high-speed industry development, Chongqing, with more than 100 days of fog per year, became another “fog city” after London. According to the report of national environment analysis in 2003, released by Tsinghua University, Chongqing was one of the ten most air-polluted cities in the world. So the environmental pollution, especially air quality, is the principal problem for this city.

The valuation assay here is designed to obtain the most suitable basket to improve air quality using the CE method, so that questions of the research are considered in five attributes: forest coverage, the rate of refuse incineration, single bus ticket price, industrial electricity price change, and change in fuel taxes (see Table 1). One attribute (the rate of refuse incineration) includes two levels, whereas the others (forest coverage, transportation ticket price, industrial electricity price, and the rate of taxes) have three different levels, respectively. Every attribute has a current level as a standard.

Respondents are required to make a choice between current situation (including current levels) and one of the alternative situations (including different levels of some attributes). According to the data in Table 1, we obtain 162 \((3\times3\times3)\) different combinations.

However, there are a huge number of the combinations for respondents, which leads to the lack of representability and manipulability of the
questionnaires. Thus the questionnaires designed are limited in four versions with eight questions about the measures of the survey for improving air quality (see Table 2).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Level</th>
<th>Name of variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest coverage/km²</td>
<td>34 000</td>
<td>Forest 1</td>
</tr>
<tr>
<td></td>
<td>35 563 (current level)</td>
<td>Forest 0</td>
</tr>
<tr>
<td></td>
<td>37 000</td>
<td>Forest 2</td>
</tr>
<tr>
<td>Rate of refuse incineration/%</td>
<td>50</td>
<td>Rate 1</td>
</tr>
<tr>
<td></td>
<td>65 (current level)</td>
<td>Rate 0</td>
</tr>
<tr>
<td>Single transportation ticket price/yuan</td>
<td>1.0</td>
<td>Ticket 1</td>
</tr>
<tr>
<td></td>
<td>2.0 (current level)</td>
<td>Ticket 0</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>Ticket 2</td>
</tr>
<tr>
<td>Annual change of industrial electricity price/%</td>
<td>–5</td>
<td>Electricity 1</td>
</tr>
<tr>
<td></td>
<td>0 (current situation)</td>
<td>Electricity 0</td>
</tr>
<tr>
<td></td>
<td>+5</td>
<td>Electricity 2</td>
</tr>
<tr>
<td>Annual change in the rate of fuel taxes/%</td>
<td>25</td>
<td>Fuel 1</td>
</tr>
<tr>
<td></td>
<td>30 (current situation)</td>
<td>Fuel 0</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>Fuel 2</td>
</tr>
</tbody>
</table>

Table 2 Choice sets

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Current situation</th>
<th>Alternative situation 1</th>
<th>Alternative situation 2</th>
<th>Alternative situation 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest coverage/km²</td>
<td>35 563</td>
<td>37 000</td>
<td>34 000</td>
<td>35 563</td>
</tr>
<tr>
<td>Rate of refuse incineration/%</td>
<td>65</td>
<td>65</td>
<td>50</td>
<td>65</td>
</tr>
<tr>
<td>Single transportation ticket price/yuan</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Annual change in industrial electricity price/%</td>
<td>0</td>
<td>0</td>
<td>–5</td>
<td>+5</td>
</tr>
<tr>
<td>Annual change in rate of fuel taxes/%</td>
<td>30</td>
<td>35</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>
4 Model specification and estimation

4.1 Choice experiment method

The CE method can be analyzed through a random utility model. For all cases, people receive stimuli, which they perceived with some error, and these determine utility they then make a choice \[4\]. The utility of alternative \(i\) is expressed as

\[
U_i = V_i + \varepsilon_i, \quad (1)
\]

where \(V_i\) is a deterministic component and \(\varepsilon_i\) is a stochastic component.

The starting utility model for Consumer \(i\) evaluating Alternative \(j\) is

\[
U_{ij} = V_i + \varepsilon_{ij} = \beta X_{ij} + \varepsilon_{ij}, \quad (2)
\]

where \(U\) is the direct utility; \(V\) is the indirect utility; \(X\) is the choice and individual characteristics; and \(\varepsilon\) is the residual (all unobservable aspects).

Because every consumer selected the optimal individual utility from choice sets, the probability of choosing alternative \(i\) instead of alternative \(j\) is displayed as

\[
P_{ij} = \Pr[U_{mi} > U_{mj}, \forall j \in C, i \neq j] = \Pr[V_{mi} - V_{mj} > \varepsilon_{mi} - \varepsilon_{mj}, \forall j \in C, i \neq j], \quad (3)
\]

where \(C\) is the set of all possible alternatives. This probability function can be only integrated by using a multi-dimensional integral, which takes a closed form for certain choices of distribution for \(\varepsilon\).

McFadden \[4\] proved that the probability of choosing an alternative over another is unaffected by the presence/absence of any additional alternatives in the choice set. The function is

\[
P_{ij} = \frac{e^{\varepsilon_{mi}}}{\sum_{m \in \Omega} e^{\varepsilon_{mj}}}, \quad (4)
\]

where \(\lambda\) is the scale parameter. At the same time, \(V_{mi}\) is a linear function, and in Eq. (1), \(V_{mi} = \beta X_{mi}\); herein \(\beta_i\) is the coefficient of utility of Alternative \(i\). In this time, the estimated coefficients do not give any economic insight per se (sign and inference are valid). The marginal effects have to be calculated from \(\beta\).

Using maximum likelihood estimates (MLE), we can obtain the log-likelihood function described as

\[
\log L = \sum_{i=1}^{n} \sum_{j=1}^{J} y_{ij} \log \left( \frac{e^{\beta X_{ij}}}{\sum_{j=1}^{J} e^{\beta X_{ij}}} \right), \quad (5)
\]

where \(y_{ij}\) is the indicating variable.

Hanemann \[5\] came up with a function of welfare compensation surplus meeting the demand theory. When getting the estimated value of parametric vectors, we can calculate the variation of the welfare with the variation of the sets. The variation of the welfare from \(X^0\) to \(X^1\) is as follows.

\[
CS = -\frac{1}{\alpha} \left[ \ln \left( \sum e^{\beta z_1} \right) - \ln \left( \sum e^{\beta z_0} \right) \right], \quad (6)
\]

where \(\alpha\) is the welfare value of income.

According to Eq. (6), we calculate the Willingness to pay (WTP).

\[
WTP_i = \frac{\beta}{\beta_m}, \quad (7)
\]

where \(\beta_i\) is the coefficient of estimation of every attribute in all situations; \(\beta_m\) is the estimator of the current level of transportation ticket price.

The general form of the CE models is

\[
V_i = \alpha_i + \beta(Y - Tax_i) + \gamma(Z_i), \quad (8)
\]
where $\alpha_i$ is the alternative specific constant; $Y$ is the income; Tax, is the tax in Alternative $i$; and $Z_i$ is the vector of all another attributes.

All the attributes in the choice experiment are input as continuous variables.

After sorting all the information from the 200 questionnaires, we obtained totally 800 observations which were input into the econometrics software, STATA, and used conditional logit model to get the results listed in Table 3.

Table 3  Conditional logit coefficients in the choice experiment

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter</th>
<th>Level of $t$</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest 1</td>
<td>(0.421)</td>
<td>(3.400)</td>
<td>0.490</td>
</tr>
<tr>
<td>Forest 0</td>
<td>0.293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest 2</td>
<td>0.472</td>
<td>(2.140)</td>
<td>1.660</td>
</tr>
<tr>
<td>Rate 1</td>
<td>0.147</td>
<td>1.800</td>
<td>1.560</td>
</tr>
<tr>
<td>Rate 0</td>
<td>(0.431)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ticket 1</td>
<td>0.049</td>
<td>1.950</td>
<td>1.280</td>
</tr>
<tr>
<td>Ticket 0</td>
<td>0.012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ticket 2</td>
<td>(0.025)</td>
<td>(1.100)</td>
<td>0.330</td>
</tr>
<tr>
<td>Electricity 1</td>
<td>0.278</td>
<td>(1.860)</td>
<td>2.670</td>
</tr>
<tr>
<td>Electricity 0</td>
<td>(0.102)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity 2</td>
<td>(0.251)</td>
<td>3.170</td>
<td>0.710</td>
</tr>
<tr>
<td>Fuel 1</td>
<td>0.694</td>
<td>2.000</td>
<td>1.920</td>
</tr>
<tr>
<td>Fuel 0</td>
<td>0.320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel 2</td>
<td>(0.434)</td>
<td>(2.920)</td>
<td>0.890</td>
</tr>
</tbody>
</table>

Notes: The number of the choice sets is 800; Log likelihood is (298.476); LR chi2 (11) is 173.570; and the pseudo $R^2$ is 0.179.

As can be seen in Table 3, the statistical results show that there is no significant difference in rate 0 and fuel 0 when the confidence level is over 10%. Meanwhile, the pseudo $R^2=0.179\ >0.1$ was maintained in an acceptable range [6].

The levels of the parameters indicate the significance of the attributes to residents. Especially the parameter of fuel 2 (-0.434) is the poorest support of residents, namely the lowest resident satisfaction. In addition, the parameter of fuel 1 (0.694) is the most popular in all the level of fuel taxes. It is obvious that the parameter of fuel 0 (0.32) is higher than that of fuel 2. It is showed that residents preferred to have a lower rate of fuel taxes.

Similarly, forest coverage is the second important aspect for residents in as shown in Table 3. The parameter of forest 2 is the highest in the three levels and that of forest 1 is the smallest. Due to this situation, we could recognize that the public would like to enjoy more forest area to improve the air quality.

The third significant element to residents was the rate of refuse incineration. The most unacceptable level is rate 0(-0.431). It is shown that the attitude of residents is that increasing the rate of refuse incineration is a terrible idea to better the air quality.

The transportation ticket price is located in the last of all elements. Residents think the current level of the ticket (0.012) has a slight influence on air quality. Consequently an obvious upward trend is seen in the parameter of ticket 1, ticket 0 and ticket 2.
Because the parameters of the non-linear model could not explain the levels of all attributes as the marginal effects directly, we need to have odds ratios, calculated by the software, to analyze the effects.

Odds ratio = \( \frac{\text{Odds ratio exp.}, j}{\beta_j} \),
in which \( \beta_j \) is the stimator of parameter on level \( j \).
Hence, an odds ratio is a relative value indicating the change of a selected probability, caused by some level of attributes, due to the interplay of these attributes. We could find every level of an attribute has a positive or negative influence on the resident choice. For example, when other levels of attributes held on the current level, the decrease of forest coverage (forest 1) results in reducing the selected probability of the new situation. If the current level of forest coverage is changed to forest 2, the selected probability of the new situation is 1.66 times as much as that of the current situation. The largest value of odds ratio is that of electricity 1, which is 2.670, and the lowest is that of ticket 2, which is 0.33.

We find that more forest coverage has a positive influence, and the falls of another attributes lead to negative influences in the air quality.

### 4.2 Social welfare method

The welfare economics aims at the field of public economics and maximizing the value of social welfare. To achieve the goal, the individual average welfare is taken as a standard. In a known resource and environment system, the changes of the economical values reflect the influences of the welfare. Therefore, the whole value of the city resource and environment system and the marginal values of attribute changes can be shown as the individual average welfare. And WTP is the mean of welfare level when every attribute changes.

Basing on the conditional logit model, we calculate the average WTP of all respondents, namely forest, rate, ticket, electricity and fuel, through Eq. (7). The results are listed in Table 4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>WTP (yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest 1</td>
<td>47.21</td>
</tr>
<tr>
<td>Forest 0</td>
<td>19.15</td>
</tr>
<tr>
<td>Forest 2</td>
<td>28.06</td>
</tr>
<tr>
<td>Rate 1</td>
<td>27.65</td>
</tr>
<tr>
<td>Rate 0</td>
<td>9.43</td>
</tr>
<tr>
<td>Electricity 1</td>
<td>20.96</td>
</tr>
<tr>
<td>Electricity 0</td>
<td>-27.65</td>
</tr>
<tr>
<td>Electricity 2</td>
<td>57.86</td>
</tr>
<tr>
<td>Fuel 1</td>
<td>45.42</td>
</tr>
<tr>
<td>Fuel 0</td>
<td>21.91</td>
</tr>
<tr>
<td>Fuel 2</td>
<td>23.51</td>
</tr>
</tbody>
</table>

As can be seen in Table 4, the maximization of WTP in the forest coverage is forest 2, up to 28.06 yuan, while the minimum is forest 1 (−47.21 yuan). And WTP of the current level is 19.15 yuan. It is indicated that increasing forest coverage can be an approach to better the air quality for most of residents. The WTP just rises by 8.91 yuan from forest 0 to forest 2, but decreases by 66.36 yuan from forest 0 to forest 1. In the levels of the rate of refuse incineration, the WTP of current level is 9.43 yuan and that of rate 1 is −27.65 yuan.

For the three levels of industrial electricity price, the WTP is positive for electricity 0 and electricity 2, 28.38 yuan and 57.86 yuan, respectively. The poorest situation is electricity 1 which does not meet the requirements of residents to provide better air quality.

For the three levels of the rate of fuel taxes, the WTP of fuel 1 is 45.42 yuan, the WTP of fuel 0 is
–21.91 yuan, and the WTP of fuel 2 is –23.51 yuan. The WTP of fuel 0 and that of fuel 2 are negative, possibly because residents might choose other vehicle rather than driving their own cars. When the rate of taxes decreases from rate 0 to rate 1, the WTP increases by 67.33 yuan. However, the increase of the rate lonely leads to lose 1.5 yuan. These situations might result from that residents experience similar feelings when the rate rises continuously. So the decrease of the rate could improve the level of the welfare significantly.

According to Table 4 and the previous analysis, we could calculate $WTP_{basis-level}$.

$$WTP_{basis-level} = \sum_{j\in K} WTP_j,$$

where $K$ is the $k$ kinds of alternatives. Meanwhile, we could get the total welfares that falls into three different types. The WTP of the current, the best and the worse are as listed in Table 5.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Current</th>
<th>Best</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>19.15</td>
<td>28.06</td>
<td>(47.21)</td>
</tr>
<tr>
<td>Rate</td>
<td>9.43</td>
<td>9.43</td>
<td>(27.65)</td>
</tr>
<tr>
<td>Electricity</td>
<td>(28.38)</td>
<td>57.86</td>
<td>(28.38)</td>
</tr>
<tr>
<td>Fuel</td>
<td>(21.91)</td>
<td>45.42</td>
<td>(23.51)</td>
</tr>
<tr>
<td>Total welfare</td>
<td>(21.71)</td>
<td>140.77</td>
<td>(126.75)</td>
</tr>
</tbody>
</table>

The best type of the welfare shows that the air quality is to be further improved in the future.

5 Conclusion

The choice experiment model has been used widely in researching environmental problems because of its characteristics and advantages. Nevertheless, every environmental problem has its unique natural sources, structures and factors, and the result of valuation is also different. In this study, we choose the air quality of Chongqing as the research object, valued by the choice experiment model with designed questionnaires, to discuss the best approach of improving the air quality. Based on the research, we have drawn the following conclusions.

1) The choice experiment method has several positive features. Firstly, the method can help us test the value of attributes and effects of selected possibility on the welfare model. Moreover, the application of choice experiment supports an approach to examine the gaps between the current situation and alternative situations. Due to this advantage, the scope of single variable impacts can be analyzed.

2) Considering the five attributes, the rate of fuel taxes has the most important influence, the forest coverage occupies the location of second most essential, the importance of the rate of refuse incineration is ranked at the third place, industrial electricity price change is the forth and transportation ticket price is the weakest aspect.

3) Regarding the specification and estimation of WTP, the higher welfare follows the positive developments of forest, electricity and fuel. In additional, the maximization of WTP is the WTP of electricity 2, which is 57.86 yuan; whereas the minimum is the WTP of forest 1, which is –47.21 yuan.

4) The economical value of the air quality is –21.71 yuan per person per year. The best value is 140.77 yuan and the worst is –126.75 yuan.

References
