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Measuring the Value of Windbreak and Sand–fixation in the Sandstorm Source Control Project in and around Beijing and Tianjin based on CVM's Different Inquiry Methods

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Based on the Contingent Value Method (CVM), this paper uses a telephone interview to random sampling residents in Beijing to survey the annual household's willingness to pay for the value of windbreak and sand–fixation effects in *the Sandstorm Source Control Project around the Beijing and Tianjin (Project)*; at the same time the annual economic value of the *Program* is calculated. The result of the research shows that in Beijing, with open–ended method, per household's willingness to pay for *Project* is from 100 to 136.81 CHY (Chinese Yuan) on average; while it's from 110 to 143 CHY with double–bounded dichotomous choice method. According to the WTP of local residents, the evaluated annual value of *Project* is from 611 to 642 million CHY.

Key words: Sandstorm Source Control Project in and around Beijing and Tianjin (Project), Externality of agriculture and forestry, Contingent valuation method (CVM), Willingness to pay (WTP)

INTRODUCTION

In order to reduce the violent sandstorm's threats to the area around the Beijing and Tianjin, the China's government has launched the Sandstorm Source Control Project in and around Beijing and Tianjin (Project), which is aiming at taking advantage of agricultural positive externality of forestation and grassland to solve the severe environmental problems around the vicinity of Beijing and Tianjin (Bo Huang *et al*., 2009). There is a need of cost–benefit analysis for the Project in order to provide some efficient implications for policy decision–makers. Compared to the cost of Project estimated by the detailed labor and capital input, the economic benefits and value of Project is difficult to be calculated because the project's benefits include ecological, social and economic aspects. Especially the ecological value is harder and therefore it is significant for the Project and policy makers to quantify the project's all benefits.

Ecological benefit is from the positive externality of agriculture and forestry. Since the value of externality is not involved in markets, it is difficult to estimate them by using the common value assessment method. Contingent Valuation Method is a method to be based on Hypothetical Market and is an effective method to estimate agricultural and forestry's external benefits in the absence of markets or surrogated markets.

Domestic application of CVM for the ecological benefits estimation is still in the stay of primary stage. Zhang and Xu (2003) did a successful study on the value of ecological recovery value in the Ejina Township of Inner Mongolia Autonomous Religion and Zhangye District in Gansu Province. However, in the term of the Sandstorm Source Control Project in and around Beijing and Tianjin, there are few studies to focusing on the economic evaluation of ecological value. The scholars pay more attentions on some techniques to evaluate ecological value but don't carry out them for practice. The study on the Project conducted by National Key Forestry Program's Socio–economic Impacts Monitoring Center (2005) only gave some descriptions and didn't estimate the project's ecological benefits quantitatively. Wang Xinyan *et al*. (2005) only confirmed the effectiveness of CVM in these studies, but in this study one single assessment method was adopted and its function is limited.

In the Project, the windbreak and sand–fixation is the most important ecological function. So the paper focuses on the economic evaluation on the value of windbreak and sand–fixation based on the CVM, and try to answer the following two questions: (1) How much is the annual economic value of windbreak and sand–fixation of Project ? (2) Are the estimation results consistent when we use different inquiry methods of CVM to survey interviewees in the activity of estimating Project's ecological value?

METHODOLOGY

CVM is often used in the survey to the consumers on the Willingness to Pay (WTP) or Willingness to Accept (WTA) in order to estimate economic value of goods which are lack of markets or alternative markets.

Inquiry methods of CVM include the discrete and continuous types. In order to compare the influences of different methods on their results, the open–ended

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method in discrete type and double–bound dichotomous choice method in continuous type are used to assess the value of Project.

Open–ended Method

Open–ended method allows interviewees to state their maximum willingness to pay or willingness to accept for environmental improvement. This method is simple and can remove the effects of initially–presented amount on final results. However, the errors could be produced because of decrease of interviewees' respond on inquiry based on their mental burden.

The data collected by open–ended method to estimate WTP in two following ways. Firstly, we can calculate the mean and median value of WTP by using descriptive statistics analysis, and then analyze the determinants of WTP by using contingency table and chi–square test. Secondly, we can construct a WTP model to analyze the determinants by regression analysis.

Double–bound Dichotomous Choice Method

Double–bound Dichotomous Choice Method is a follow–up bids inquiry approach. In the survey, an interviewee has to respond "Yes" (willing to pay) or "No" (unwilling to pay) to each bid.

In the first bid, the interviewer asks the individual respondent whether he or she would pay a given amount of payment, B_i to secure a given improvement in environmental quality. If the individual responds "yes" to the first bid, the second bid (to be denoted B_i^u) will be a greater payment than the first bid ($B^i < B_i^u$). If the individual responds "No" to the first bid, the second bid (to be denoted B_i^d) will be a smaller payment than the first bid ($B^i > B_i^d$). Thus, there are four different possible outcomes (yes–yes, no–no, yes–no, no–yes). This method is involved with a bid process and for the interviewees it is easier to respond to the inquiry. Thus, we can gain a estimated result close to the true willingness of respondents.

In the Double–bound Dichotomous Choice Method, G(•) denotes the cumulative distribution function with a given WTP. The likelihood to answer yes–yes, no–no, and yes–no, no–yes by respondents is denoted respectively as follows:

$$\begin{aligned}\pi^{yy}(B_i<B_i^u)&=\Pr\{B_i\le \max WTP \text{ and } dB_i^u\le \max WTP\}\\&=\Pr\{B_i\le \max WTP \mid B_i^u\le \max WTP\}\Pr\{B_i^u\\&\le \max WTP\}=\Pr\{B_i^u\le \max WTP\}\\&=1-G(B_i^u;\ \theta)\end{aligned}\tag{1}$$

$$\begin{aligned}\pi^{nn}(B_i<B_i^d)&=\Pr\{B_i>\max WTP \text{ and } dB_i^d>\max WTP\}\\&=G(B_i^d;\ \theta)\end{aligned}\tag{2}$$

$$\begin{aligned}\pi^{yn}(B_i<B_i^u)&=\Pr\{B_i\le \max WTP\le B_i^u\}=G(B_i^u;\ \theta)\\&-G(B_i;\ \theta)\end{aligned}\tag{3}$$

$$\begin{aligned}\pi^{ny}(B_i, B_i^d)&=\Pr\{B_i\ge \max WTP\ge B_i^d\}=G(B_i;\ \theta)\\&-G(B_i^d;\ \theta)\end{aligned}\tag{4}$$

In the models, MaxWTP denotes the true maximum WTP of interviewees.

Given the responding likelihood showed above, the log–likelihood function of Double–bound Dichotomous Choice Method is:

$$\begin{aligned}\ln L^D(\theta)&=\sum_{i=1}^{N}\{d_i^{yy}\ln\pi^{yy}(B_i,B_i^u)+d_i^{nn}\ln\pi^{nn}(B_i,B_i^d)\\&+d_i^{yn}\ln\pi^{yn}(B_i,B_i^u)+d_i^{ny}\ln\pi^{ny}(B_i,B_i^d)\}\\&=\sum_{i=1}^{N}\{d_i^{yy}\ln(1-G(B_i^u;\theta))+d_i^{nn}\ln G(B_i^d;\theta)\\&+d_i^{yn}\ln(G(B_i^u;\theta)-G(B_i;\theta))\\&+d_i^{ny}\ln(G(B_i;\theta)-G(B_i^d;\theta))\}\end{aligned}\tag{5}$$

Among them, i denotes i–th interviewee, d_i^{yy}, d_i^{nn}, d_i^{yn}, d_i^{ny} are indicator functions. For example, when responding sequence of interviewee is yes–yes, d_i^{yy} equals 1, otherwise, 0.

Assuming that the errors of likelihood function obey a certain distribution. So we can adopt the different specific function forms to estimate the above functions. This paper adopts the "CVM Calculation By Excel" software to do the model estimation based on the logit–log model, Weibull and Turnbull survival analysis. Using the coefficient of estimation, we can estimate the mean and median of WTP, and then obtain their probability distributions.

DATA

Questionnaires

The questionnaires in this paper include the following items: (1) to illustrate purposes of investigation; (2) to estimate the interviewees' effectiveness and environmental perception; (3) to understand the awareness of the Sandstorm Source Control Project around the Beijing and Tianjin, (4) to build the hypothetical markets and to choose the means of payment which means public fund in this paper; (5) to inquire the Willingness to Pay; (5) to investigate the socio–demographic characteristics of sample.

In these questionnaires, question based on Open–ended Method is as follows:

In order to reduce the occurrence of sandstorms in Beijing and improve the environmental quality around you, you think that your family household could afford up to extra _____ CHY annually.

And the question based on Double–bound Dichotomous Choice Method is as follows:

The investment for the Sandstorm Source Control Project in and around Beijing and Tianjin has mainly been from financial input by the central and local governments. In order to reduce the occurrence of sandstorms in Beijing significantly, if you are asked to pay an extra amount of _____ CHY annually to set up a public fund to assist the government in the control of sandstorm source, are you willing to do something for it?

□Yes, if the amount rises to _____ CHY, are you

Table 1. Socio–demographic characteristics of sample

Variable	Description	Frequency	Percentage (%)	Variable	Description	Frequency	Percentage (%)
Gender	Female	200	49.50	Average Month spending per household (CHY)	≤ 1499	130	32.18
	Male	204	50.50		1500–1999	80	19.80
Age (years)	≤ 24	64	15.84		2000–2499	90	22.28
	25–30	83	20.54		2500–2999	33	8.17
	31–40	71	17.57		3000–3499	24	5.94
	41–50	78	19.31		3500–3999	12	2.97
	51–60	45	11.14		4000–4499	8	1.98
	≥ 60	63	15.59		≥4500	27	6.68
Education	Primary School and lower	26	6.44	Occupation	Civil servants	18	4.46
	Secondary School	51	12.62		Researcher	15	3.71
	High School	79	19.55		Teacher	13	3.22
	Vocational School	34	8.42		Enterprise Staff	149	36.88
	Junior College	77	19.06		Student	40	9.90
	Undergraduate	114	28.22		Retirees	88	21.78
	Graduate and above	23	5.69		Unemployment	33	8.17
					Other	48	11.88
Whether to have the experience of environmental Protection	Yes	88	21.78	Whether to know the *Project*	Yes	150	37.13
	No	316	78.22		No	254	62.87

still willing to do it? □Yes□No

□No, if the amount decreases to _____ CHY, are you still willing to do it? □Yes□No

□Not applicable

Data in this paper was collected by telephone interview on February and March in 2006 for residents located in Beijing based on the need to assess the benefits of the Sandstorm Source Control Project in and around Beijing and Tianjin. The telephone numbers are randomly chosen by the computer, and interviewees are limited to more than 18 years old who have lived in Beijing for three years or above. We chose 4800 different telephone numbers and call 3200 of them. But only 464 persons are willing to be interviewed, which is 17.9%. Finally we collected 404 valid questionnaires, which accounted for 87.1% of the total interviewees.

Socio–demographic characteristics of sample

The basic socio–demographic characteristics of sample are summarized in Table 1. Compared to the 1% population census done in Beijing in 2005, there were not more differences between the population census and our survey in terms of sex and age distribution. The average education level in our survey is higher than that of the population census because people with high level of education are more willing to accept out telephone interview and understand our questionnaires better.

ESTIMATION RESULT

Open–ended Method and estimation of WTP

Statistical description of average WTP

We collected 297 valid questionnaires based on open–ended method and 189 persons of them are willing to pay and 108 are not. The average WTP of all interviewees is 136.81 CHY and the median value is 100 CHY.

There exists a large difference among people who have different education levels. The higher the persons' educational level is, the more they would like to pay for. The interviewees who hold master degree or above are willing to pay 159.44 CHY, followed by people who hold a certificate or diploma (148.33 CHY) , hold undergraduate degree (126.61 CHY), hold a high–school degree (94.00 CHY) and do not finish high school degree (50 CHY).

In terms of average household month–spending, except two special internal which are 2000–2499 and 4000–4499, the higher the households' month–spending is, the more they would like to pay for. However, the ratio of payment to average month–spending of per household is higher in the lower average month–spending household.

Model regression of average WTP

We choose two linear models to do the regression. The first model is:

$$Y = \beta_0 + \beta_1 Cog1 + \beta_2 Cog2 + \beta_3 Sex + \beta_4 Age + \beta_5 Job + \beta_6 Exp + \beta_7 Edu1 + \beta_8 Edu2 + \beta_9 Pop + \beta_{10} Inc + \varepsilon \quad (6)$$

Based on (6), we put the interviewees' perception on environment into model and obtain model (7):

$$Y = \beta_0 + \beta_1 Cog1 + \beta_2 Cog2 + \beta_3 Sex + \beta_4 Age + \beta_5 Job + \beta_6 Exp + \beta_7 Edu1 + \beta_8 Edu2 + \beta_9 Pop + \beta_{10} Inc + \beta_{11} Env1 + \beta_{12} Env2 + \beta_{13} Env3 + \beta_{14} Env4 + \beta_{15} Env5 + \varepsilon \quad (7)$$

Table 2. The WTP based on the Different Average Household Month–spending and Interviewees' Education Level

Monthly Expenditure (CHY)	Average WTP	Sample	Education	Average WTP	Sample
≤1499	70.21	97	Primary or lower	50.00	20
1500–1999	131.64	58	Secondary School	53.85	39
2000–2499	101.14	66	High School	94.00	55
2500–2999	104.11	28	Vocational School	76.67	30
3000–3499	115.71	14	Junior College	148.33	51
3500–3999	172.22	9	Undergraduate	126.61	84
4000–4499	107.00	5	Master and above	159.44	18
≥4500	195.00	20			

Table 3. Definitions, statistical characteristics and anticipated effects

Variable	Definition	Mean	S.E.	Expected direction
Cog1	Whether or not the sandstorms affect your daily life 1=No, 0=Yes	0.885	0.019	+
Cog2	Whether or not you heard about the Sandstorm Source Control Project around Beijing and Tianjin 1=No, 0=Yes	0.372	0.029	+
Sex	Gender 1=male, 0=female	0.528	0.030	?
Age(years)	Age, a continuous variable	42.681	0.973	–
Job	Are you a company employee? 1=Yes, 0=No	0.392	0.029	+
Exp	Do you have experiences of protecting environment or forestry? 1=Yes, 0=No	0.181	0.023	+
Edu1	Do you finish high school education? 1=Yes, 0=No	0.281	0.027	+
Edu2	Do you have an undergraduate degree or above? 1=Yes, 0=No	0.524	0.030	+
Pop	Number of your family member, a continuous variable	3.344	0.075	+
Inc (CHY)	Monthly expenditure of your family 0=less than 1499, 1=1500–1999, 2=2000–2499, 3=2500–2999, 4=3000–3499, 5=3500–3999, 6=4000–4499, 7=more than 4500	1.868	0.119	+
Env1	Concerns on air quality forecast, 2=Much, 1=Moderately, 0=Never	1.372	0.042	+
Env2	Concerns on city greening 2=Much, 1= Moderately, 1=Never	1.358	0.400	+
Env3	Concerns on auto emission 2=Much, 1= Moderately, 2=Never	1.229	0.044	?
Env4	Concerns on industrial emission 2=Much, 1= Moderately, 3=Never	1.052	0.048	?
Env5	Concerns on breathing problems 2=Much, 1= Moderately, 4=Never	1.292	0.046	+

In model (7), Y is dependent variable which indicates residents' annual average WTP for the Project. Definitions, statistical characteristics and anticipated effects of the explanatory variables in model (7) are summarized in Table 3.

The estimation result is indicated in Table 4. Based on the model (6), we find that in the level of 10% significance, the variables of age, Edu2 and Pop are significant, and variable of Inc is significant in the 5% significant level. According to F test, the regression is significant under 1% significant level. Therefore, we obtain the regression model (8) based on model (6):

$$Y = 80.340 - 0.940Age + 41.057Edu2 + 11.192Pop + 9.369Inc \quad (8)$$

When the average value of various variables are put into the regression model, we obtain the average WTP of households, which is 116.67 CHY and is exactly between mean and median value of the sample.

Based on the model (7), the variables of Age and Env3 are significant under the 10% significant level and Inc is significant under the 5% significant level. According to F test, the regression is significant under the 1% significant level. Therefore, we obtain that the regression model (9) based on the model (7):

$$Y = 71.266 - 1.062Age + 10.449Inc + 23.232Env3 \quad (9)$$

When the average values of various variables are put into the regression model, we obtain the average WTP of households is 74.01 CHY, which is lower than the mean or median value of sample. Thus, we choose model (6) as our WTP model and the average WTP of households in Beijing is 116.67 CHY. The determinants of residents' WTP include age (Age), education level of undergraduate or above (Edu2), number of family members (Pop) and households' monthly expenditure (Inc). These variables have the same effects as the expected.

Table 4. Regression results of the model based on Open–ended Method

Variable	Model (6)	Model (7)
R Square	0.107	0.120
Constant	80.340 (1.803*)	71.266 (1.670*)
Cog1	–13.731 (–0.560)	–20.174 (–0.796)
Cog2	–6.726 (–0.394)	–9.224 (–0.523)
Sex	–15.536 (–0.964)	–17.281 (–1.029)
Age	–0.940 (–1.681*)	–1.062 (–1.781*)
Job	18.287 (1.052)	16.085 (0.912)
Exp	–13.059 (–0.639)	–18.155 (–0.861)
Edu1	18.682 (0.769)	18.406 (0.745)
Edu2	41.057 (1.669*)	38.104 (1.508)
Pop	11.192 (1.788*)	10.140 (1.592)
Inc	9.369 (2.207**)	10.449 (2.407**)
Env1	——	0.517 (–0.039)
Env2	——	2.314 (0.171)
Env3	——	23.232 (1.819*)
Env4	——	–12.011 (–0.984)
Env5	——	6.484 (0.563)
F value	3.315 (2.32***)	2.473 (2.32***)

Note: t value in the parentheses, *, **, *** denote significance under 10%,5%,1% significant level, respectively

Double–bound Dichotomous Choice Method and estimation of WTP

The estimation results for the WTP probability model based on Double–bound Dichotomous Choice Method are indicated in Table 5. In the maximum likelihood estimation of Log–logit model and Weibull survival analysis, all variables are significant under the 1% significance level based on the T test. In Turnbull survival analysis, the other clusters are significant in 1% except for 110–120 CHY, which is significant in 5%. We can use the coefficients to estimate the WTP because of the excellent estimation results.

WTP probability distribution based on the specific assessment methods is shown in Figure 1, which is used to estimate the mean and median value of residents' WTP.

In terms of logit–log model, the median value of WTP is 100 CHY, 186 CHY in the non–truncated regression and 115 CHY in the truncated regression. There is a huge difference among these three results.

In terms of Weibull survival analysis, the median value of WTP is 102 CHY, 117 CHY in the non–truncated regression and 111 CHY in the truncated regression.

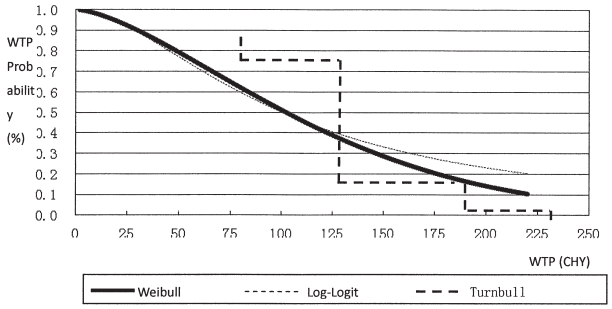

Fig. 1. Distribution of WTP probability.

Table 5. Estimation results for the WTP probability model based on DDCM

☆ Maximum Likelihood Estimation for Logit–log Model (n=397, log likelihood=–441.468)			
Variable	Coefficient	t value	P value
constant	8.0183	15.352	0.000***
lnB	–1.7397	–14.285	0.000***
☆ Maximum Likelihood Estimation for Weibull survival analysis (n=39, log likelihood=–417.549)			
Variable	Coefficient	t value	P value
Location	4.8663	95.326	0.000***
Scale	0.6494	16.257	0.000***
☆ Maximum Likelihood Estimation for Turnbull survival analysis (n=397)			
Lower	Upper	Survival probability	t value	P value
0	20	1.092	72.00	0.000***
20	80	1.045	134.57	0.000***
80	100	0.864	43.59	0.000***
100	120	0.303	10.80	0.000***
120	180	0.196	5.80	0.000***
180	220	0.061	1.97	0.050**
220	+∞	0.000		

Table 6. Estimation results of WTP based on DDCM

Index	*Logit–log* model	*Weibull* survival analysis	*Turnbull* survival analysis
Median value	100	102	120
Mean value(non–truncated regression)	186	117	143

There is no more difference among these three results. In terms of Turnbull survival analysis, the median value of WTP is 120 CHY and the mean value is 143 CHY. These two values are both greater than those in the logit–log model and Weibull survival analysis, as indicated in Table 6.

Therefore, after eliminating the abnormal values, we can estimate the WTP based on Double–bound Dichotomous Choice Method, which is approximately 110–143 CHY.

Estimation of the annual economic value of the Project

The formula used to estimate the annual economic value of the Project is:

$$Value = WTP = \sum_{i=1}^{n} WTP_i = \overline{WTP} \times n$$

Where, $\overline{\text{WTP}}$ is the annual WTP of households in Beijing for the Sandstorm Source Control Project in and around Beijing and Tianjin, n is the total amount of households in Beijing (in this paper,n equals 5.24 million)

When putting the annual WTP of households in Beijing into the formula, we estimate the annual economic value of the Project in Beijing is approximately 524–717 million CHY based on Open–ended Method, and 524–749 million CHY based on Double–bound Dichotomous Choice Method. When combined with the results of statistical description, we estimate that the average economic value of the Project in Beijing is 641.89 million CHY, with the median value of 611.35 million CHY (see Table 7).

The estimated value approximately takes up 10.94–11.49% of total investment amount of the Project, which shows that the residents in Beijing have high appraisal of the Project. For the residents in Beijing, the Sandstorm Source Control Project around Beijing and

Table 7. Estimation of the annual economic value for the Project's benefits

Open–ended method		Double–bound Dichotomous Choice Method			
indicator	value	indicator	Log–logit model	Weibull survival analysis	Turnbull survival analysis
Mean	71688	Median	52400	53448	62880
Median	52400	Mean (Non–truncated)	97464	61308	74932
Estimator	61135	Mean (Truncated)	60260	58164	

Tianjin has a high ratio of output to input.

CONCLUSIONS AND DISCUSSIONS

Conclusions

The main conclusions are as follows:

The annual WTP of households in Beijing is 100–136.81 CHY based on Open–ended Method, and 100–143 Chinese yuan based on Double–bound Dichotomous Choice Method. The annual economic value of the Project in Beijing is 611–642 million CHY.

Based on the research to the use of CVM in the exploration of economic estimation for the Sandstorm Source Control Project in and around Beijing and Tianjin, we find that there exists consistency in the estimates taken by Open–ended Method and Double–bound Dichotomous Choice Method, which shows that it is efficient to apply CVM method to the research for the external benefits of agroforestry in China.

Furthermore, the research shows that the WTP model based on Open–ended Method and Weibull survival analysis based on Double–bound Dichotomous Choice Method are relatively efficient. So, a prior consideration should be taken when we undergo WTP (or WTA) estimation.

At the same time it is also feasible in China to undertake the telephone interview method to do the survey, which is able to collect the same efficient data as the other survey methods.

Discussions

In spite of the limitation of sample who are constrained in Beijing, the estimation of economic value of the Project is still of great value.

Firstly, the economic value in this paper denotes the amount that the residents in Beijing are willing to pay for the sandstorm control, which is based on their total average WTP. As a rational man, the resident is willing to pay the same amount for the treatment as the benefits he receives from it. Thus, the total WTP can be considered as the annual economic value of the Project. Certainly, it is a subjective estimate, rather than an actually–generated economic value of the Project. Even so, it is of great significance to do the cost–and–benefit analysis for the external benefits from the agro–forestry.

Secondly, this paper does not pay more attentions to the consumers' time preference. According to the rational man assumption of economics, the interviewees' WTP shows their payment for actual value and long–term value, which involves interviewees' time preference. Thus, it is advisable to take time preference into consideration when we estimate the long–term benefits of agro–forestry or its relative projects. Since the external benefits of agro–forestry will last for several years, we should investigate the interviewees about their WTP by different stages, in order to estimate the economic value of the external benefits in the certain stage.

Thirdly, the Sandstorm Source Control Project in and around Beijing and Tianjin touches upon five provinces in Northern China, while its benefits of the Project exceed the limit of five provinces. If the Project could control sandstorm effectively, the external benefits are even widened to Korea and Japan, which becomes the inter–country commons. Even so, since the Project is mainly aiming at reducing the sandstorms in Beijing, it is still significant to do this kind of research.

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