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Abstract

China has long suffered from severe haze pollution due to coal consumption in rural areas. One possible solution is the promotion of a new electric heating system called "low temperature air source heat pump (LTHP) technology." This paper explores the possibility that the public will accept the LTHP for electric heating. To this end, we elicit people's willingness to adopt (WTA) and willingness to pay (WTP) for the LTHP technology and sociodemographic and perception information by conducting field surveys of 579 households and empirically characterize the determinants of public acceptance. The analysis reveals that income, science literacy and local environmental concern positively affect WTA and WTP, while global environmental concern does not show any significance. Contrary to our initial expectation, people in mountainous areas express the highest WTA and WTP, followed by those in hilly and plains areas. Overall, these findings suggest that efforts to promote the technology could begin in mountainous areas and move to hilly and then to plains areas, thereby advancing public education on local environmental concerns and science literacy. Adopting such a plan has the potential to successfully promote the electric heating system in the lowest-cost manner and ensure a cleaner environment through the shift from coal to electricity in rural Beijing.

Key Words: public acceptance; air pollution; electric heating; rural Beijing

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Contents

Nomenclature

CV	Contingent valuation
HEV	Hybrid electric vehicle
LTHP	Low temperature air source heat pump
PM	Particulate matter
RMB	Renminbi, Chinese currency
TCE	Tons of Coal Equivalent
WTA	Willingness to adopt
WTP	Willingness to pay

1 Introduction

China has suffered from severe smog and haze pollution since 2012, and the high concentration of $\mathrm{PM}_{2.5}$ has attracted considerable attention in China (Li and Liu, 2014, Wu et al., 2016).[1] As has been reported, coal consumption was responsible for 22.4 % of the $\mathrm{PM}_{2.5}$ concentration in Beijing (Beijing

[1]PM (particulate matter) is the sum of all solid and liquid particles suspended in the air. Particles 2.5 micrometers and smaller in diameter, denoted $\mathrm{PM}_{2.5}$, pose the greatest health risks.

Municipal Environmental Protection Bureau, 2014). Wu et al. (2016) find that coal consumption in rural Beijing has reached 4 million tons of coal equivalent (TCE) per year, and 92 % of that is used for space heating, with considerable pollution being generated from residential sectors due to incomplete coal combustion. To combat this problem, a switch in the household energy source from coal to electricity is advocated in rural Beijing (General Office of Beijing Municipal People's Government, 2014), and the government plans to broadly promote and subsidize electric heating using LTHP technology, which has been scientifically demonstrated to be effective in many aspects of rural life (General Office of Beijing Municipal People's Government, 2014, Chai et al., 2016).[2]

Many governmental policies intended to promote certain technologies among the public have been unsuccessful and led to significant social costs (Hallsworth et al., 2011). Thus, it is argued that policies used to promote technologies should be designed in advance and, crucially, on the basis of scientific evidence regarding public acceptance and needs (Sutcliffe and Court, 2005, Hallsworth et al., 2011). Moreover, there has been an important policy debate over how to promote LTHP technology in rural areas of China to secure a cleaner environment (Lu, 2016). Given this state of affairs, this paper seeks to empirically characterize the determinants of public acceptance of LTHP technology, thereby contributing to policy design for solutions to pollution problems in China.

Several papers have studied the factors that influence the selection of sustainable or environmentally friendly residential heating systems in developed countries. For instance, Sopha et al. (2010) compare the choice among electric heating systems, heat pumps and wood pellet stoves and argue that sociodemographic factors, communication among households, the perceived importance of heating system attributes and the decision strategy influence Norwegian homeowners' decisions. Similarly, Lillemo et al. (2013) find that household and demographic factors, environmental attitudes and people's motives affect households' investment in heating and the choice among four types of heating equipment in Norway. Karytsas and Theodoropoulou (2014) also show that age, income, education and the presence of a person in a household with an occupation or interest in the environment, technology or engineering or an awareness of renewable energy resources and alternative technologies affects people's willingness to adopt ground source heat pumps in Greece. Overall, these studies address the adoption or

[2] Detailed information on the LTHP is provided in the appendix.

selection among several sustainable heating systems in developed countries, where these sustainable heating systems are available and traded on the market, and conclude that basic socioeconomic factors and attitudes toward the environment are fundamental determinants of technology choices.

Few studies focus on the determinants of the public acceptance of environmentally friendly electric heating systems when the heating system in question is not traded on the market and will instead be promoted through government policy. Moreover, the public acceptance of environmentally friendly technologies has not yet been analyzed in the context of emerging and developing economies, where air pollution is more serious than in developed countries and people's ways of thinking are expected to be different (Gupta et al., 2011). Among developing countries, China is known to suffer from particularly heavy air pollution and as a primary contributor to haze and smog pollution, attracting considerable attention from the media and other countries such as South Korea and Japan (Sun et al., 2016). Since LTHP technology has been scientifically demonstrated to be effective in coping with air pollution in rural China, this paper explores the potential for public acceptance and promotion policies for LTHP technology by empirically examining its determinants. To this end, we collect data though face-to-face surveys in rural Beijing with respect to people's willingness to adopt (WTA) and willingness to pay (WTP) for LTHP technology to measure public acceptance, socioeconomic characteristics, such as income and education, and perception variables such as science literacy and environmental concerns. We also consider the area-specific effect of the public acceptance of LTHP technology, as where the LTHP promotion project should begin (in plains, hilly or mountainous areas) is an important point in the policy debate.

2 Data description and methodology

Beijing is the capital city of China and is also the country's political, economic and cultural center. It is located in the northeastern China and surrounded by Tianjin Municipality and Hebei Province. Beijing consists of 16 administrative county-level districts, including 6 urban and 10 suburban and rural districts. While Beijing has a total area of 16 410.5 km^2, only 1368.3 km^2 is urban area, while the rest is broadly suburban and rural (Beijing Municipal Government, 2012). In this study, we focus primarily on analyzing rural Beijing for several reasons. First, Beijing's energy consumption structure is dominated by coal, and the city has suffered from smog and haze in recent years. Second, Beijing has taken the leading role in China with respect to replacing coal with cleaner substitutes. Third, there is substantial variation in geographical status, sociodemographic characteristics and economic levels across the rural areas in Beijing. The survey areas in our research comprise the following five suburban and rural districts (figure 1): Yanqing, Miyun, Pinggu, Fangshan and Daxing. Regarding geographical and socioeconomic differences, we categorize these five districts into three groups: mountainous districts (Yanqing and Miyun), hilly districts (Pinggu and Fangshan) and plains districts (Daxing).

[Figure 1 about here.]

[Table 1 about here.]

For this research, we conducted a field survey in rural Beijing on people's WTA and WTP for the LTHP in March 2016. Overall, a total of 579 households were randomly selected and interviewed face-to-face. Because the respondents' decision of whether to adopt the LTHP and state their maximum WTP value is a hypothetical scenario, information about the LTHP was provided and explained individually during the survey.[3] In addition to WTA and WTP for the LTHP, the survey data include socioeconomic and perception information about the households. The socioeconomic information includes age, gender, house size, education, household income, heating area and locations of houses (plains, hilly and mountainous areas), while the perception information includes science literacy and local and global environmental concerns. We hypothesize that these variables are important determinants of WTA and WTP for the LTHP. Table 1 summarizes the definition of each variable used in our analysis.

Two dependent variables: WTA and WTP

This paper uses two dependent variables for analysis: people's WTA and WTP for the environmentally friendly LTHP technology. The respondents were asked to answer two questions: (1) whether they would be willing to adopt the LTHP and (2) what their maximum WTP for the technology would be if they answered "yes" to the first question. Table 2 provides a brief description of people's WTA and

[3] The LTHP information distributed to the respondents is provided in the appendix.

WTP for the LTHP. Among the 579 respondents in rural Beijing, 53 % of them report being willing to adopt the LTHP, while the remaining 47 % are not. In particular, only 7 % of people in plains areas report being willing to adopt the LTHP. This is the lowest acceptance rate among the three area types. In contrast, 74 % of people in mountainous areas report being willing to adopt the LTHP. Table 2 also shows that people in the plains areas express the lowest WTP, at 71.05 RMB on average, while people in hilly and mountainous areas have higher WTP values of 1001.36 RMB and 992.48 RMB, respectively. Overall, people in plains areas are the least likely to adopt the LTHP and have the lowest WTP for the technology compared with their counterparts in hilly and mountainous areas, and this result can be considered unexpected or in contrast with our initial expectation.

[Table 2 about here.]

Basic socioeconomic and demographic characteristics

Table 3 provides an overview of the socioeconomic and demographic characteristics of our respondents. There is substantial variation among the survey respondents in the variables of age, household size and household heating areas. Overall, the ranges of age, household size and household heating area are 20 to 91, 1 to 11, and 12 to 500, respectively. The same tendency can be also observed with respect to these variables within each of the three area types. On an average, the annual household income is the highest in the plains areas and the lowest in the mountainous areas. People in hilly areas have the highest household income gap, ranging from 2000 RMB to 120 000 RMB per year. The respondents' education status is lower in the mountainous areas than in the plains and hilly areas.

[Table 3 about here.]

Perception variables

We collected two types of perception variables: (1) environmental concern and (2) science literacy. To precisely examine the impact of environmental concern, we adopt two measurements of environmental concern in the analysis: global environmental concern and local environmental concern. Global environmental concern comprises 12 questions, basically following Nakagawa (2017) (see table 4).

In addition to the 11 questions used in Nakagawa (2017), one item on global warming is added to the measurement, as we are also interested in studying individual technological adoption behaviors to reduce haze pollution and coal consumption. Each question is assessed on a 5-point scale: $1 =$ strongly disagree, $2 =$ disagree, $3 =$ neutral, $4 =$ agree, $5 =$ strongly agree. The global environmental concern score ranges from 12 to 60. Local environmental concern focuses more on the specific environmental issues in Beijing (table 5). Except for the 4-point score used for question 6, all other questions were rated as $1 =$ strongly disagree, $2 =$ disagree, $3 =$ neutral, $4 =$ agree, $5 =$ strongly agree. The local environmental concern score ranges from 6 to 29. Table 3 provides the summary statistics separately for global environmental and local environmental concern. On average, people in plains areas express the lowest concern regarding both local and global environmental issues, relative to those in hilly and mountainous areas. In addition, the overall minimum global environmental concern is 24, meaning that people's concern regarding global environmental issues is consistently above "strongly disagree," while the minimal concern on local issues is relatively lower.

[Table 4 about here.]

[Table 5 about here.]

Science literacy is measured by 10 questions listed in table 6 (Miller, 1998). The respondents were supposed to answer "true," "false" or "no idea" for each question. The option "no idea" is scored zero to avoid accidental correct answers. Science literacy is scored from 0 to 10 by summing up all the correct answers. As indicated by table 3, respondents' science literacy ranges from 0 to 9 in general. On average, people in mountainous areas exhibit the least science literacy but the largest standard deviation thereof, indicating broad variation in scientific knowledge, while the highest science literacy is shown by people in hilly areas.

[Table 6 about here.]

Methodology

The government plans to widely promote LTHP technology, but it remains a new product that has not been introduced or traded on the market. It is an environmentally friendly technology to reduce coal consumption and mitigate air pollution. Hence, this paper employs the contingent valuation (CV) method to examine the rural population's willingness to adopt (WTA) and willingness to pay (WTP) for the LTHP product (Ghanbarpour et al., 2014, Hamed et al., 2016, Proufoun et al., 2016, Sun et al., 2016, Verbic et al., 2016). The CV questions in this analysis are divided into two steps. In the first step, we ask whether each respondent is willing to adopt the product, given the information provided about LTHP technology. Therefore, it is a dummy variable taking value one when a respondent wants to adopt it. If the respondent answers "yes," the second step follows, and we ask the respondent her maximum WTP value for LTHP technology.

To establish public acceptance of LTHP technology, we estimate two types of regressions: (1) a probit model with a dummy variable for whether each respondent is willing to adopt the LTHP as the dependent variable and (2) a Tobit model in which each respondent's WTP is used as the dependent variable. The two models employ the same set of independent variables, which can be specified as

$$y = f(D_c, E_a, S, H_a, I, \epsilon). \quad (1)$$

Here, D_c is a set of area dummy variables, each of which represents mountainous districts (Yanqing and Miyun) and hilly districts (Pinggu and Fangshan) where a plains area (Daxing) is treated as the reference group. E_a consists of two variables: one is global environmental concern, and the other is local environmental concern. S is the science literacy scale, H_a is a set of variables at the household level such as age, gender, education, household size and housing area. Finally, I is annual household income in the year 2015, and ϵ is a disturbance term.

In the probit regression, each respondent's decision of whether to adopt LTHP technology is modeled by the dummy variable y_i that takes value 1 when respondent i is willing to adopt LTHP technology. Otherwise, $y_i = 0$. In this case, the dependent variable in y in equation (1) becomes $\text{Prob}(y_i = 1)$, and the probability that each respondent will adopt the technology is estimated by the probit regression with respect to a set of independent variables such as D_c, E_a, S, H_a and I. Specifically, the probit regression enables us to identify the marginal probability of LTHP technology adoption when a key independent variable increases by one unit, holding other factors constant. Thus, the key determinants of LTHP adoption are characterized by the probit regression as a first step.

In the Tobit regression, our focus is on the quantity of the maximum willingness to pay (WTP) expressed by respondents. When respondent i is willing to adopt the LTHP, i.e., $y_i = 1$, she is asked to express a maximum WTP, i.e., $\text{WTP}_i > 0$ for LTHP adoption. When the respondent is NOT willing to adopt the technology, this implies that $\text{WTP}_i = 0$. Since we have found a considerable portion of $\text{WTP}_i = 0$ in the sample, the Tobit regression is judged to be appropriate, and the marginal change in WTP is estimated to determine the marginal impact of the associated key determinants on WTP, using the same set of independent variables as in the probit model. We employ these two regression models to characterize public acceptance of LTHP technology from both qualitative and quantitative aspects of household decision making.

3 Results

Table 7 reports the marginal effects of the independent variables on people's WTA and WTP. In general, the variables of gender, income, science literacy, local environmental concern and the area dummies are significant factors that affect both WTA and WTP, while age has a significant impact only on WTA, and the house heating area only affects WTP. As shown in table 7, annual household income has a significantly positive effect on people's WTA and WTP, as expected. Specifically, a 10 000 RMB increase in annual household income is associated with a 2.400 % increase in the probability that people will accept the LTHP, and their WTP will accordingly increase by 128.293 RMB. This result indicates that as China's economy grows, people's tendency to adopt this technology in rural areas may gradually increase.

[Table 7 about here.]

Regarding the marginal effect of gender, we find that females are 7.800 % more willing to adopt the technology than are males. Similarly, regarding the WTP value, females are, on average, willing to pay 308.997 RMB more than males. This is not in line with the findings from Erdem et al. (2010), which indicate that in Turkey, males are likely to pay the a higher premium for hybrid electric vehicles

(HEVs) than females. A possible explanation is that coal is the primary heating resource in rural households, and females are primarily responsible for the frequent fuel replacement in coal stoves, which are inconvenient and usually generate observable smog and and a foul odor. Females are expected to clean the house every day, and thus, they may prefer to use more environmentally friendly heating products and exhibit higher WTP than males.

There is no statistically significant relationship between education and people's WTA and WTP, although the coefficients of the Tobit and probit regressions are found to be positive. Our result is consistent with the previous findings from Sun et al. (2016) that education and the WTP to address the smog crisis in China are positively correlated, but the effect is insignificant. Regarding age, our results show that it has a small positive impact on WTA (0.300 %) at the 5 % significance level but has no effect on WTP. This finding implies that older people are more interested in replacing their existing heating systems with an LTHP. This is the opposite of the finding in Sopha et al. (2010) that it is more difficult to change older people's behavior by encouraging them to switch from an existing heating system to a heat pump or wood pellet stove. This may also be because compared to younger people, due to their gradual decline in physical function and greater responsibility to the whole family, older people devote considerable attention to their own health and that of other household members. Thus, they may have a greater demand for a healthy environment, especially for warmth during a long winter.

The area of a house that needs to be heated is estimated to have a significantly negative but relatively small effect on WTP, meaning that people's WTP falls by 2.574 RMB with a 1 m^2 increase in area. Although the impact appears quite small, it is not when the impact is evaluated given a one-standard-deviation increase in house area (≈ 58.340). We find that if the area of a house is increased by one standard deviation, people's WTP decreases by 150.167 RMB ($2.574 \times 58.340 \approx 150.167$), on average. However, the probit regression indicates that the area to be heated has no significant influence on WTA. In one sense, having a larger home area means that there are more rooms to be heated. It is reasonable that respondents with large homes may be more motivated to obtain several units of the product at a time. Due to budget constraints, they are particularly incentivized to pay low prices for the LTHP. However, since the LTHP is a non-traded product without prices or subsidies, it is difficult for such respondents to clearly express their attitude on whether to adopt the technology.

Science literacy is found to have a positive relationship with both WTA and WTP for the technology. The probit model estimates that increasing the science literacy score by one point leads to a 2.100 % rise in the probability of adopting the technology. Accordingly, the Tobit regression reveals that people are willing to pay 88.077 RMB more following a one-point increase in the science literacy score. This result suggests that science literacy is an important factor that affects people's attitude and behavior toward this new environmentally friendly technology. It is expected that people with more scientific knowledge and literacy may find it easier to recognize the desirable features of the technology even in a short time. It is reasonable that they are more likely to adopt the technology in their home and have a higher willingness to pay.

One interesting finding in this paper is that local environmental concern positively affects both WTA and WTP at the 1 % significance level, while global environmental concern is insignificant. This result implies that compared to the global environmental concern, greater concern about local environmental issues induces people to be more motivated to adopt the LTHP and at higher prices. More precisely, our results reveal that a one-point increase in local environmental concern results in a 2.900 % rise in the likelihood adoption; accordingly, such people are, on average, willing to pay 94.081 RMB more to purchase the LTHP. In the context of our analysis, a one-standard-deviation increase in local environmental concern (≈ 4.040), the WTA probability and the associated WTP would increase by 11.716 % ($2.900 \times 4.040 \approx 11.716$ %) and 380.087 RMB ($94.081 \times 4.040 \approx 380.087$), respectively.

Global environmental concern has an insignificant influence on both WTA and WTP, although the sign of the coefficient is positive. This finding may reflect the fact that compared to global environmental issues, local environmental problems directly affect local people's quality of life. They may take prompt action to address specific local issues such as air pollution. In other words, the local environmental concern that people develop on the basis of their everyday life is more important for public acceptance of new electric heating systems than global environmental concern that people may have developed from consuming books, TV and other media.

Another interesting finding is that, contrary to our expectation, people living in mountainous areas express the highest WTA and WTP for the LTHP, followed by people living in hilly and plains areas. This result reveals that people living in mountainous and hilly areas are 56.900 % and 38.000 % more likely to adopt the technology and exhibit higher WTP values, 2435.239 RMB and 1851.772 RMB, respectively. One possible reason is that the remote mountainous and hilly areas suffer from lower temperatures in winter. Once they become familiar with the desirable functions of the LTHP that will be useful during cold winters, they will be more likely to accept this technology. An additional explanation is that more remote mountainous areas present fewer job opportunities due to the greater distance and lower access to urban areas. Because there are no farming activities in remote mountainous and hilly areas during the winter, people in such areas naturally have to spend more time at home and are more concerned about the indoor environment. Therefore, they are more motivated to adopt the LTHP.

In recent years, plains areas have been used as focus groups for the promotion of clean energy technologies, including LTHP technology, to achieve the target of zero coal consumption (General Office of Beijing Municipal People's Government, 2016, 2017). This may be because these plains areas have suffered from more severe haze pollution. However, our analysis finds that public acceptance of the LTHP is highest in mountainous areas, the second highest in hilly areas and the lowest in plains areas. On the basis of this result, we argue that if mountainous areas can be prioritized for LTHP promotion, it is more likely that the LTHP technology will be more successfully and efficiently accepted and distributed with lower government investment and spending on promotion. Achieving such success in mountainous areas can be expected to positively influence public acceptance of LTHP technology in other areas such as hilly and plains areas. The important findings in this paper can be summarized as follows. First, income remains a key factor in determining public acceptance of LTHP technology. Second, people with higher levels of science literacy and local environmental concern are more willing to adopt the technology by spending more money, while global environmental concern does not show any significance. Third, people in mountainous areas express the greatest interest in adopting the technology and the highest WTP, followed by those in hilly and plains areas.

4 Conclusion

Due to the importance of efficiently promoting LTHP technology to address air pollution in China, this paper has analyzed the determinants of people's willingness to adopt (WTA) and willingness to pay (WTP) for the technology in rural Beijing. We find that income, science literacy and local environmental concern are important factors that affect the likelihood of the adoption of LTHP technology, while global environmental concern does not have any effect. Regarding the important question of the type of area that the LTHP promotion should begin in, we find that people in mountainous areas express the highest WTA and WTP for the LTHP, followed by those in hilly and plains areas. We argue that people in mountainous areas are more concerned about the indoor environment and, thus, are more likely to accept LTHP technology for the following reasons. First, mountainous areas have few job opportunities other than farming because of the greater distance to and fewer means of accessing urban areas. Second, people in mountainous areas usually spend more time at home than those in plains areas because there are no farming activities in winter.

These results suggest important policy implications. While it is necessary to continuously stimulate economic development in rural China, further public education on science literacy and local environmental concern should be encouraged to motivate people to accept environmentally friendly technologies. Furthermore, our results also suggest that it would be preferable to prioritize mountainous areas in promotion strategies for LTHP technology because we observed the highest public acceptance in mountainous areas. The promotion campaign should then target hilly and plains areas, following the order of public acceptance. We believe that successes in LTHP promotion in mountainous areas will positively influence public acceptance in other areas such as hilly and plains areas, thus allowing LTHP technology to be more successfully and efficiently accepted and distributed in the lowest-cost manner. Ultimately, this will mean that households in rural Beijing will switch energy sources from coal to electricity, thereby improving the environment.

Overall, this paper provides crucial findings for decision makers regarding where to begin and how to efficiently promote the LTHP in rural Beijing. We believe that this is an important contribution to addressing excessive coal consumption in rural China. This paper might also serve as an important reference in the following respects: 1) the prospects for the adoption of this technology in other parts of China that rely heavily on coal as a heating source; 2) the development of other environmentally friendly technologies; and 3) the market prospects for manufacturers or sellers that trade in environmentally friendly technologies. Finally, we admit that this study faces limitations. Although we did our best to introduce and explain LTHP technology during the face-to-face surveys, some unavoidable and unexpected biases in WTA and WTP might exist. Therefore, further research on the public acceptance of LTHP technology could be developed and conducted to confirm the robustness of our results during the real promotion periods. Such future research is crucial to ensure the smooth transition from coal to cleaner energy in the long run.

5 Appendix: Low temperature air-source heat pump (LTHP)

The LTHP is an environmentally friendly electric heating technology. It is a mechanical compression cycle refrigeration system powered by electricity from an air source that can be reversed to heat a room. It has the desirable characteristics of low initial investment and operating costs, ease of installation and operation, and no pollution emissions. The steady-state coefficient of performance (COP) will not be lower than 2.0 on average throughout a winter season when the temperature is higher than or equal to 20 °C. Note that in the actual application all of the information was provided to respondents in the local Chinese language. Because they are familiar with the expenses from using coal, we only provided the respondents details regarding the running costs for LTHP, as scientifically identified in demonstration projects.

[Table 8 about here.]

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Figure 1: Administrative divisions of Beijing

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Table 1: Description of the variables

Variable	Description
Area dummy variables (Base group = Plains areas)	
Mountainous dummy	This variable takes value 1 when a respondent lives in a mountainous area. Otherwise, 0.
Hilly dummy	This variable taks value 1 when a respondent lives in a hilly area. Otherwise, 0.
Environmental concern and perception factors	
Global environmental concern	This is a score on 12 global environmental issues, ranging from 12 to 60.
Local environmental concern	This is a score on 6 local (Beijing) environmental concerns, ranging from 6 to 29.
Science literacy scale	This is a score of the answers to 10 questions related to general science ranging from 0 to 10.
Household variable	
Age	Age of a respondent
Gender	This is a dummy variable taking value 1 when the respondent is male. Otherwise, 0.
Education	This variable represents the respondent's years of schooling.
Household size	The number of household or family members.
Heating area	Area in square meters that needs to be heated in winter.
Income	Annual household income for the year 2015 in 10 000 RMB

Table 2: Summary statistics of the dependent variables

Dependent variable	Areas			Overall
	Plains area	Hilly area	Mountainous area	
WTA (Yes $= 1$, No $= 0$)				
Average (Median)[1]	0.07 (0)	0.66 (1)	0.74 (1)	0.53 (1)
SD[2]	0.26	0.47	0.44	0.5
Min	0	0	0	0
Max	1	1	1	1
WTP (RMB)				
Average (Median)	71.05 (0)	1001.36 (1000)	992.48 (1000)	755.1 (500)
SD	256.73	954.09	783.31	886.37
Min	0	0	0	0
Max	1200	3000	3000	3000
Sample size	152	294	133	579

[1] Median in parentheses.
[2] SD refers to standard deviation.

Table 3: Summary statistics of the independent variables

Independent variable	Areas			Overall
	Plains area	Hilly area	Mountainous area	
Age (Years)				
Average (Median)[1]	53.88 (54)	54.28 (55.5)	56.48 (55)	54.68 (55)
SD[2]	10.64	13.88	11.39	12.56
Min	21	20	20	20
Max	86	88	91	91
Gender (Female = 0)				
Average (Median)	0.8 (1)	0.56 (1)	0.65 (1)	0.64 (1)
SD	0.4	0.5	0.48	0.48
Min	0	0	0	0
Max	1	1	1	1
Household size (persons)				
Average (Median)	4.25 (4)	3.86 (4)	3.21 (3)	3.81 (4)
SD	1.59	1.57	1.4	1.58
Min	1	1	1	1
Max	8	11	7	11
Education (years)				
Average (Median)	8.34 (9)	8.91 (9)	7.90 (9)	8.53 (9)
SD	2.26	2.61	1.86	2.40
Min	6	6	6	6
Max	16	16	12	16
Income (10 000 RMB per year)				
Average (Median)	2.95 (3)	2.84 (3)	1.43 (1)	2.55 (2)
SD	1.78	1.98	0.98	1.84
Min	0.2	0.2	0.2	0.2
Max	8	12	5	12
Heating areas (m^2)				
Average (Median)	123.82 (100)	109.09 (100)	82.06 (80)	106.74 (100)
SD	61.56	61.86	33.35	58.34
Min	30	12	20	12
Max	300	500	200	500
Science literacy (The theoretical range is 0-10)				
Average (Median)	4.24 (4)	4.78 (5)	3.52 (3)	4.35 (4)
SD	1.78	2.06	2.58	2.18
Min	0	0	0	0
Max	8	9	9	9
Local environmental concern (The theoretical range is 6-29)				
Average (Median)	18.26 (18)	21.80 (23)	19.56 (18)	20.36 (20)
SD	3.31	3.81	4.05	4.04
Min	9	7	10	7
Max	27	29	29	29
Global environmental concern (The theoretical range is 12-60)				
Average (Median)	41.32 (42)	45.19 (45)	44.04 (46)	43.91 (44)
SD	5.73	7.72	7.06	7.26
Min	33	29	24	24
Max	56	60	60	60
Sample size	152	294	133	579

[1] Median in parentheses.
[2] SD refers to standard deviation.

Table 4: Measures of global environmental concern

Questions	Description
1	I am concerned about global warming.
2	I am concerned about the relationship between energy and the environment.
3	I am concerned about environmental protection.
4	I like reading books about environmental problems.
5	I want to consider environmental problems proactively.
6	I would like to learn more about environmental problems.
7	I watch TV programs or read articles on the environment with interest.
8	I am interested in the biosphere.
9	I am interested in natural energy such as solar energy.
10	I would like to be actively engaged in environmental problems.
11	I am concerned about energy problems.
12	I am interested in the protection of species in danger of extinction.

Table 5: Measures for local environmental concern

Questions	Description
1	I am concerned about air quality in Beijing.
2	I am concerned about water/soil pollution problems in Beijing.
3	I am concerned about news or knowledge about air pollution control in Beijing
4	I am concerned about the harmful effect of air pollution to health in Beijing.
5	I am concerned about the daily air quality index forecast.
6	I am concerned about the trade-off between life convenience and energy conservation:
	a. Life convenience always has higher priority.
	b. Conserve energy without sacrificing life convenience.
	c. Conserve environment even if life convenience is sacrificed to some extent.
	d. Environmental conservation is always more important.

Table 6: Measures of science literacy

Questions	Description
1	The temperature of the core of the earth is extremely high.
2	All radioactive materials are artificial.
3	The sex of a baby is determined by his/her father's genes.
4	Laser beams can be generated by collecting sonic waves together.
5	Electrons are smaller than atoms.
6	Antibiotics kill viruses like bacteria.
7	The universe was born in a huge explosion.
8	The continents have been moving over the millennia and they will continue moving.
9	Human beings evolved from primitive animals.
10	The earth is moving around the sun.

Table 7: Marginal effects of probit and Tobit regressions

	Probit	Tobit
	WTA[1]	WTP[2]
Socioeconomic variables		
Age	0.003**	6.614
	(0.002)	(5.318)
Gender	-0.078**	-308.997**
	(0.034)	(119.049)
Education	0.009	14.359
	(0.008)	(28.531)
Household size	-0.006	19.887
	(0.012)	(39.858)
Heating area	-0.000	-2.574**
	(0.000)	(1.069)
Income	0.024**	128.293***
	(0.010)	(34.909)
Environmental concern and perception variables		
Global environmental concern	0.002	3.225
	(0.002)	(8.092)
Local environmental concern	0.029***	94.081***
	(0.004)	(15.426)
Science literacy scale	0.021**	88.077***
	(0.008)	(26.601)
Area dummy variables (Base group = Plains areas)		
Mountainous dummy	0.569***	2435.239***
	(0.039)	(228.440)
Hilly dummy	0.380***	1851.772***
	(0.037)	(206.005)

***significant at the 1 percent level, **at the 5 percent level and *at the 10 percent level.

[1] "WTA" represents willingness to adopt.

[2] "WTP" represents willingness to pay.

Table 8: Performance of the LTHP for 80 m^2 residence in typical rural homes

	LTHP	LTHP with peak-valley price policy[1]
Electricity price (RMB/kWh)	0.5	0.1 - 0.5
Annual energy consumption (kWh)	2500	2500
Annual heating fee (RMB)	1250	920
Annual heating fees per square meter (RMB)	15	11.5
Annual $PM_{2.5}$ emission	0	0

[1] With a peak-valley time price policy, the price would be 0.1 RMB/kWh at the peak and 0.5 RMB/kWh in the valley. Assuming that the LTHP operates 24 hours per day, the heating fee is identified as in table 8 based on realistic assumptions regarding the peak and valley times.