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Measuring Method and Empirical Study on Public Willingness-to-pay for Environmental Conservation Under Spatial Scale

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Abstract

In view of the fact that there're spatial differences in Willingness-to-pay (WTP) among the public, it is of great significance to explore the Contingent Valuation Method (CVM) by distance under spatial scale to solve the problem of cost sharing of environmental management. This paper constructs the spatial lag model of WTP and discusses the spatial interaction relationship of WTP in combination of Moran's I Index and spatial partitioned effects, which remedies the deficiency of traditional CVM model in spatial effects analysis. Based on the characteristics that double-bounded dichotomous choice CVM data is interval data, the probability utility function is used to propose the parameter estimation method for the spatial lag model of WTP. Songhua River is taken as an example to make empirical analysis, the results indicate: (1) The spatial lag model of WTP is effective to deal with the data of dichotomous choice CVM in spatial scale. (2) There're distance decay effects of WTP under different spatial scales and the degree of public recognition is the main motivation affecting the decay. (3) The ecological value of the Songhua River in 2012 is 8.315 billion CNY. The research provides a new approach for CVM to evaluate the resource and environmental value and enhances the scientificity and effectiveness of the results with CVM evaluation method.

Keywords: *Spatial Effect; Spatial Lag; Contingent Valuation Method (CVM); Double-bounded Dichotomous Choice; Willingness-to-pay (WTP)*

1. Introduction

Drainage basins are the most valuable ecological resources the human beings are relying on. They not only provide high quality water sources and abundant species but also play an important role in water conservation, biodiversity conservation and support of the economic development of human beings. Generally, people are concerning more about the use value brought by the ecological service system of drainage basins while ignoring the non-use values of the drainage basins themselves. Existing studies [1-2] have made evaluations on the values of the drainage basins by Contingent Valuation Method. According to the findings, the life support values are huge. If the values of the drainage basin resources themselves are ignored and the current resources are developed and utilized in an unconstrained manner, the ecological system would be damaged and the sustainable development may be adversely affected.

Contingent Valuation Method [3] is a widely used method to evaluate the non-market values such as selection value, heritage value and existence value of environment goods.

It reveals the public Willingness to pay or Willingness to accept (WTA) for environmental goods change by establishing a hypothetical market in form of questionnaires based on the principle of utility maximization [4-6]. The Blue Ribbon Panel appointed by National Oceanic and Atmospheric Administration (NOAA) has made

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multifaceted evaluations on CVM, affirmed the applicability of CVM and recommended dichotomous choice induction technique as the preferred question format in CVM research [7]. The dichotomous choice has the superiority that it can fully simulate the market consumption behaviors, provides optional payment amount for environmental conservation to the respondents. The respondents only need to answer whether they'd like to pay such amount, which reduces the deviation of valuation of the respondents [8-9]. Therefore, this questionnaire format is widely used in the world [10].

In the application of CVM into the practices of environmental management, a common problem is the unfairness of "cost sharing". The public are unwilling to pay certain expenses to make environmental treatment on those ecological environments that they have never been to or even heard of. And they'd rather pay for the treatment of resources bearing vital interests with themselves. Therefore, it is proposed by many scholars that geographic location is an important factor to solve this problem. Sutherland and Walsh (1985) takes the distance between the respondent and the environmental goods as an independent variable into the evaluation model of the non-market values of the water resource [11]. He founds that, there's negative correlation between the WTP on environment goods and the distance of the respondents. In other words, the WTP decreases with the increase of the distance, which is also called the distance decay effect of WTP [12]. This is also a relatively earlier case in evaluation of environment goods values under spatial scale. Based on this, many scholars have developed a series of studies on the distance decay effect of the WTP. Bateman *et al.* (2006, 2009) holds that there're distance decay effects in the WTP on environment goods of both the users and non-users under different spatial scales [13-14]. However, Bateman's research fails to make comparison analysis on the degree of WTP decay of users and non-users. Then Hanley (2003) proposes the decay function between the distance and the WTP on environmental goods of the respondents [15]. The results indicate that the users have more obvious decay rate compared with the non-users. Schaafsma (2012) analyzes the impact of the directional effects from several environmental goods on the WTP of respondents and finds that the WTP of non-users have more obvious distance decay effects in the drainage basin values after the environment is improved [16].

Such studies divide the respondents into groups based on distances and compare the difference of WTP on environment goods by respondents in different distance belts. They represent the distance decay effects of WTP and redefine the computation method for the total values [17].Therefore, regionalism is quite necessary. However, the existing studies are quite subjective in regionalism and lack of objective quantitative basis. In addition, the assertions of decay relationship cannot directly explain the motivation of the distance decay effect in WTP. Therefore, further exploration and analysis is still required on the distance decay effect of WTP. The two key words of distance decay effects are distance and lag structure, which may be understood that the transfer of economic benefits is made by lag structure [18]. And the lag structure depends on the spatial contiguous relationship and regional scale [19]. Baltagi *et al.* (2014) apply the spatial lag model to analyze the housing price variations of 353 areas in the US and prove that there're spatial autocorrelation in housing price fluctuation of contiguous areas [20]. In summary, we assume that there's spatial autocorrelation of WTP under different scales. The relationship of spatial interaction among the WTP of respondents from different areas may be analyzed by establishing the spatial lag model of WTP.

Compared with existing studies, the main contributions of this paper are as follows: Firstly, we define the distance between respondents and the evaluation object, propose the objective quantitative basis on regionalism by applying the Enhanced Objective Cluster Analysis (EOCA) [21] based on distance and establish the CVM evaluation approach under spatial scales. Secondly, we give consideration to the spatial differences of the WTP among the public, construct the spatial lag model of WTP, and discuss the relationship of spatial interaction between WTP in combination with Moran's I Index and spatial partitioned effects, which remedies the deficiency of traditional CVM model in spatial effects analysis. Thirdly, based on the characteristics that the double-bounded dichotomous choice CVM data is interval data, the probability utility function is used to propose the parameter estimation method for the spatial lag model of WTP.

This paper researches the measuring method on public WTP on environment treatment under spatial scale based on existing studies [22-23].The non-use values of Songhua River is taken as an example to make empirical analysis. The results indicate that the spatial lag model of WTP is effective and reasonable to deal with the data of dichotomous choice CVM under spatial scale by comparing the logarithm WTP function model and verify the distance decay effects of WTP. The motivation and mechanism of distance decay effect in WTP is further explained by Moran'I Index and spatial partitioned effects method. The conclusion provides a new approach for evaluation of ecological environmental benefit values with CVM and provides reference basis for the cost and benefit allocation of related policies about ecological environment.

2. Methodology

2.1. Basic Concept

In order to explore the differences between public willingness to pay under different spatial scales. Firstly, we put forward the following two concepts: the distance and the calculate method of ecological total values.

2.1.1. Definition of Distance: This paper proposes two hypotheses: Firstly, if the evaluation object is a mountain or river, it is regarded as a curve according to the spatial distribution under the spatial perspective. Secondly, the investigation takes administrative region as basic units, and takes the coordinates of the government in these regions as the geographic coordinates of the respondents from these regions. In other words, the geographic coordinates of the respondents from the same administrative region are regarded as being from the same point. The distance between the respondents and the evaluation object is defined as the vertical distance from the point to the curve and denoted by dis, hereinafter referred to as the "distance". As the product of the direction vector of the point on the curve and its normal vector (the vertical distance from point to curve) is zero, as shown in Figure 1. The curve function of evaluation objects can be obtained by fitting of the polynomial of the points evaluation object through on the map and denoted by $f(x,y)=0$. $A(a_i,b_i)$ is the i^{th} plane coordinates (geographic coordinates) among the respondents. The direction vector at $B(x_i,y_i)$ of curve is $\vec{C}\left(1, dy/dx|_{x=x_i}\right)$. When $\overrightarrow{AB}$ is vertical to $\vec{C}$, $\overrightarrow{AB}$ is the vertical distance dis_i from $A(a_i,b_i)$ to curve f, as shown in Equation (1):

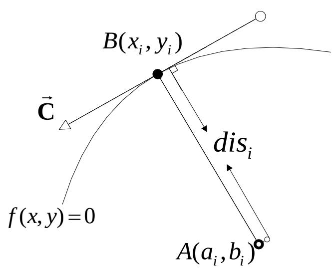


Figure 1. Fundamental of Direction Vector Method

$$\overrightarrow{AB}\cdot\vec{C}=0 \tag{1}$$

The set of plane coordinate of the respondents is denoted by $U = (a_i, b_i), i = 1, 2, \ldots, M$, The formula set is acquired as follows:

$$\begin{cases} (x_i - a_i, y_i - b_i) \cdot (1, dy/dx\big|_{x=x_i}) = 0 \\ f(x_i, y_i) = 0 \end{cases} \tag{2}$$

The distance is:

$$dis_i = \sqrt{(x_i - a_i)^2 + (y_i - b_i)^2} \tag{3}$$

2.1.2. Calculation Method of Total Benefit Values: There're differences in environment preference among respondents under different spatial scales. The EOCA Method is applied to divide the respondents of different distances into sub-regions of different spatial scales, which gives the objective basis and quantification principle of regionalism. Therefore, the total ecological values of the environment goods should be the sum of the products of the average WTP and the number of population in each sub-regions. The calculation formula[24] is as follows:

$$WTP_{\text{Total}} = \sum_j \overline{WTP_j} \cdot P_j^+ \cdot H_j \tag{4}$$

Where, $\overline{WTP_j}$ is the average WTP of the respondents willing to pay in the j^{th} sub-region; P_j^+ is the probability of the respondents willing to pay, called positive payment rate. H_j is the total population.

2.2. Spatial Lag Model of WTP

To research the spatial interaction relationship of WTP among neighboring sub-regions within a spatial system, a spatial lag model of WTP is constructed as follows with individual WTP as the observation value:

$$\ln WTP = (I - \rho W)^{-1} \left(\beta_0 + \sum_{k=1}^{K} X_k \beta_k + \varepsilon \right) \tag{5}$$

Where, $\ln WTP$ is the dependent variable matrix of $N \times n$ Order; N is the number of sub-regions; n is the number of samples in each sub-region; W is the spatial weight matrix of $N \times N$ Oder; When i is neighbor to j , then $W_{ij} = 1$; When $i = j$ or i is not neighbor to j , then $W_{ij} = 0$. X_k is the k^{th} attribute variable matrix of $N \times n$ Order; β_k is the coefficient of the k^{th} attribute variable; β_0 is the constant; ρ is the spatial autocorrelation coefficient of neighbor sub-regions; When $\rho = 0$, equation (5) is the linear regression expression of logarithm WTP function without spatial character [13].

2.2.1. Spatial Partitioned Effects of WTP: To analyze the influence mechanism of spatial effect of WTP among different sub-sub-regions, the spatial effect [25] of WTP may be calculated as follows according to Equation (6):

$$S_k(W)_{ij} = (I - \rho W)^{-1} \beta_k, \; i, j = 1, 2, \ldots, N \tag{6}$$

Where, $S_k(W)$ represent the spatial effect matrix of the k^{th} attribute variable; $S_k(W)_{ij}$ represent the spatial interaction of j^{th} Sub-region to i^{th} Sub-region.

$$S_k(W)_{ij} = \begin{cases} Direct\ effect\ of\ Region\ i, & i = j \\ Indirect\ effect\ of\ Region\ i, & i \neq j \\ Total\ spatial\ effect\ of\ Region\ i, & \sum j \end{cases} \tag{7}$$

$S_k(W)$ may also be expressed as the sum form of the direct effects and indirect effects of multiple-order neighboring sub-regions [26].

$$S_k(W) \approx I\beta_k + \left[\rho W\beta_k + \rho^2 W^2\beta_k + \rho^3 W^3\beta_k + \ldots + \rho^q W^q\beta_k\right] \tag{8}$$

Where, q is the number of neighboring sub-region orders; the indirect effect is in the brackets, indicating the lag structure of the spatial effects is superposed by the effects from different orders.

2.2.2. Parameter Estimation: For the data of double-bounded dichotomous choice CVM is interval data, we combine the spatial lag model of WTP with probability utility function to make parameter estimation by maximum likelihood method.

In the questionnaire format of double-bounded dichotomous choice CVM, we firstly provide the respondents with an initial bid amount and the responses of respondents is “Yes” or “No”. If the respondents is affirmative on initial bid T, provide a higher bid value TU or provide a lower bidding value TL instead. The responses of the respondents can be in four types: “Yes-Yes”, “Yes-No”, “No-Yes” and “No-No”, which respectively denoted by YY, YN, NY, NN and the probabilities are π^{YY}, π^{YN}, π^{NY}, π^{NN}: Assuming $\varepsilon \sim N\left(0,\sigma^2 I_N\right)$, TU, T and TL are all $N \times n$ order matrixes, the probability utility function of spatial lag model of WTP can be expressed as:

$$\begin{aligned}
\pi^{YY} &= \pi^{YY}\left(\ln TU < \ln WTP\right) = \pi^{YY}\left(\left(\left(I-\rho W\right)\ln TU - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma < \varepsilon/\sigma\right) \\
&= 1 - \Phi\left(\left(\left(I-\rho W\right)\ln TU - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right) \\
\pi^{YN} &= \pi^{YN}\left(\ln T < \ln WTP < \ln T^{u}\right) \\
&= \Phi\left(\left(\left(I-\rho W\right)\ln TU - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right) - \Phi\left(\left(\left(I-\rho W\right)\ln T - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right) \\
\pi^{NY} &= \pi^{NY}\left(\ln TL < \ln WTP < \ln T\right) \\
&= \Phi\left(\left(\left(I-\rho W\right)\ln T - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right) - \Phi\left(\left(\left(I-\rho W\right)\ln TL - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right) \\
\pi^{NN} &= \pi^{NN}\left(\ln WTP < \ln TL\right) = \Phi\left(\left(\left(I-\rho W\right)\ln TL - \left(\hat\beta_0 + \sum_{k=1}^{K} X_k\hat\beta_k\right)\right)\Big/\sigma\right)
\end{aligned} \tag{9}$$

The logarithm likelihood equation may be written as:

$$\ln L = \sum_{i=1}^{n}\left(d_i^{YY}\ln\pi_i^{YY} + d_i^{YN}\ln\pi_i^{YN} + d_i^{NY}\ln\pi_i^{NY} + d_i^{NN}\ln\pi_i^{NN}\right) \tag{10}$$

Where, d_i^{YY}, d_i^{YN}, d_i^{NY}, d_i^{NN} are dummy variables, which respectively represent the responses of the respondents; if the response is “Yes-Yes”, then $d_i^{YY}=1$, and other dummy variables are 0. The definition of d_i^{YN}, d_i^{NY}, d_i^{NN} and d_i^{YY} is the same.

2.3. Spatial Autocorrelation of WTP

The Global Moran’s I Index and local Moran’s I are comprehensively used to measure the spatial autocorrelation of WTP in each sub-region. The Global Moran’s I Index is used to test whether it is similar, different or independent among the neighbor WTP of the entire research area. The global Moran’s I Index of WTP in the sub-region is expressed as:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(WTP_i - \overline{WTP}\right)\left(WTP_j - \overline{WTP}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}\left(WTP_i - \overline{WTP}\right)^2} \quad (11)$$

Where, n is the number of samples in the sub-region; $\overline{WTP}$ is the average WTP of the samples in the sub-region; W_{ij} is the spatial weight matrix of the sub-region. The local Moran's I Index is used to measure whether there're similar or different observation values gathering together in the local region. The local Moran's I Index of WTP in the sub-region is expressed as:

$$I_i = \frac{l\left(WTP_i - \overline{WTP}\right)\sum_{j\neq i}^{l} \omega_{ij}\left(WTP_j - \overline{WTP}\right)}{\sum_{i=1}^{l}\left(WTP_i - \overline{WTP}\right)^2} \quad (12)$$

Where, l is the number of neighbored of the i^{th} region in each sub-region; $\overline{WTP}$ is the average value in i^{th} region and its neighbored; ω_{ij} is the spatial weight matrix made by the i^{th} region and its neighbored.

3. Empirical Design

3.1. Songhua River Overview

Songhua River is located in the north of Northeast China. It crosses Jilin Province, Heilongjiang Province and the Inner Mongolia Autonomous Region and enters Russia in Fuyuan. The length and the total resource amount of Songhua River are both leading in China and the river is the main source for domestic water in the Northeast China. In recent years, a great number of industrial sewage and domestic sewage has been discharged into the Songhua River. Presently, the environmental treatment of the Songhua River has been listed into the protection program on key drainage basins. This paper applies Contingent Valuation Method to make investigations on the WTP of the residents in the counties of Heilongjiang Province and Jilin Province that are covered by Songhua River Drainage Area and then calculates the aggregation of environmental benefit values of Songhua River.

3.2. Questionnaire Design

The residents in some cities and counties of Heilongjiang Province and Jilin Province that are covered by Songhua River Drainage Area are selected for the questionnaire. Double-bounded dichotomous choice CVM questionnaire is used to evaluate the aggregation of environmental benefit values of Songhua River (main stream and two branch streams). The questionnaire contents including, the basic information survey about Songhua River, the initial bids for dichotomous choice questions and the setup of reasonable range based on current researches with expert consultation and pre-investigation. The payment methods involve taxation, donation, establishment of protection funds, voluntary labor, *etc*. The questionnaire involves three parts: The first part is the investigation on public ecological awareness of Songhua River, including the degree of understanding, concern, satisfaction on environment protection and development conditions, *etc*. The second part is for the induction of WTP in the questionnaire of double-bounded dichotomous choice. Seven types of questionnaire are setup, with initial bids respectively of: 1, 5, 10, 20, 50, 100 and 200 (CNY). The third part is the investigation on the social, economic and geographic attributes of the respondents. Interview and online survey methods are used in a combined manner. Totally 1,660 questionnaires are distributed, including 963 for interview and 697 for online survey.

3.3. Basic Statistics

Totally 1,653 copies of questionnaire are collected. The recovery rate is 99.59%. The invalid questionnaires are removed, and the numbers of valid questionnaires are 1,222. Among the valid ones, there are 165 protest responses, which are regarded as zero payment. The positive payment rate of the entire region is 86.50%, the WTP distribution table is shown in Table 1.

Table 1. Double-Bounded Dichotomous Choice WTP Distribution

Type	T	TU	TL	YY		YN		NY		NN		Total	Opposite	P^+	Valid
				n	p	n	p	n	p	n	p	n			
A	1	3		143	96.62%	5	3.38%	0	0.00%	0	0.00%	148	7	95.48%	155
B	5	10	3	144	88.89%	11	6.79%	4	2.47%	3	1.85%	162	9	94.74%	171
C	10	20	5	132	81.48%	21	12.96%	6	3.70%	3	1.85%	162	24	87.10%	186
D	20	30	10	105	63.25%	31	18.67%	29	17.47%	1	0.60%	166	22	88.30%	188
E	50	100	30	70	48.61%	44	30.56%	26	18.06%	4	2.78%	144	32	81.82%	176
F	100	200	50	60	45.80%	33	25.19%	26	19.85%	12	9.16%	131	39	77.06%	170
G	200	500	100	52	36.11%	43	29.86%	30	20.83%	19	13.19%	144	32	81.92%	177
Total				706	66.73%	188	17.79%	121	11.45%	42	3.97%	1057	165	86.50%	1222

Note: Type: Types of Questionnaire; T: The initial bid; TU: The higher bid; TL: The lower bid; YY: Yes-Yes; YN: Yes-No; NY: NO-Yes; NN: No-No; Opposite: Refuse to Pay; P+: The positive payment rate; Valid: The Number of valid questionnaires.

3.4. Regionalism

This research takes prefecture-level cities involved as basic units to construct the sub-regions, and totally 15 cities are involved, then $M = 15$. We digitize the geographic map of the Songhua River and correlate to x-axis, y-axis onto the plane coordinate system and fit of the polynomial of the points Songhua River through on the geographic map to draw the curvilinear function of the three rivers of Songhua River drainage basin (Nenjiang River, The Second Songhua River and Songhua River). Formula (2) and Formula (3) are applied to obtain the distances between the respondent and the three rivers, of which the minimum value is the shortest distance between the respondent and Songhua River.

The EOCA method is applied to divide the respondents from different distances into sub-regions, and the number of the sub-regions calculated in this paper is 3. The enhanced consistency criterion is the smallest, which is 0.001. Therefore, the research area is divided into three spatial sub-regions under spatial perspective. The results of regionalism are shown in Figure 2.

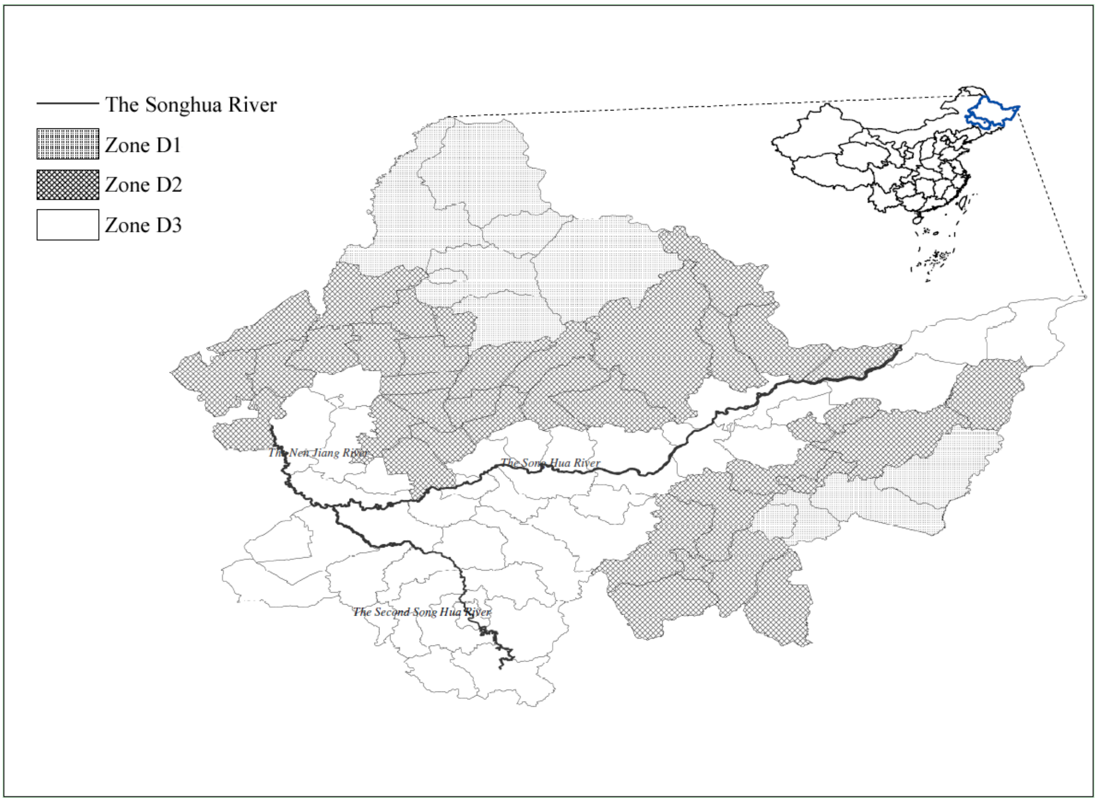


Figure 2. Regionalism Results

As shown in Figure 2, sub-region D_1 involves Jiamusi, Harbin, Jilin, Changchun, Songyuan and Daqing. The same characteristic of this sub-region is that all the cities are along the Songhua River. The sub-region D_2 involves Hegang, Yichun, Suihua, Qiqihar, Shuangyashan, Qitaihe and Mudanjiang that they are not by Songhua River but neighbor to those cities along Songhua River. From the aspect of distance, the distances of cities in D_2 to Songhua River are greater than those of D_1.Sub-region D_3 involves Jixi and Heihe, which are not cities along the Songhua Rivers and such cities are not neighbor to those cities in D_1. Comparing with D_2, the distance to the Songhua River is greater. The regionalism results are consistent with the geographic locations of the cities, which represents the favorable classification feature of EOCA method. The basic regional statistics are shown in Table 2.

Table 2. Statistics on Number of Valid Questionnaires

D	YY		YN		NY		NN		Opposite		P^+	Total	
	n	p	n	p	n	p	n	p	n	p		n	p
D_1	192	0.72	29	0.11	16	0.06	29	0.11	29	8.77%	0.90	295	100%
D_2	181	0.68	37	0.14	25	0.09	23	0.09	63	21.03%	0.81	329	100%
D_3	138	0.52	44	0.17	23	0.09	61	0.23	73	28.83%	0.78	339	100%

Note: D_1: along Songhua River; D_2: not along Songhua River but neighbor to D_1; D_3: not along Songhua River or not neighbor to D_1.

According to Table 2, the numbers of valid questionnaires in D_1, D_2 and D_3 are respectively 295, 329 and 339, of which the opposite questionnaires are respectively 29, 63 and 73. The rates of positive payment are respectively 0.9, 0.81 and 0.78. The regional sample distribution conforms to the distance decay effect of WTP.

4. Empirical Results

4.1. Basic Model and Estimation

The logarithm of individual WTP is selected as dependent variable. The stepwise regression analysis method is used to remove the indistinctive independent variables. Five variables are retained. The degree of public recognition is the average value of five measurement projects. The definition of independent variables and the impact symbol anticipation of the dependent variable is shown in Table 3.

Table 3. Defintion of Independent Variables

Variable	Definition	Anticipation sign
male	Ordinal variable, two grades (female, male=1; male ,male=2)	-
age	Ordinal variable, six grades (<20,age=1;21-30,age=2;31-40,age=3; 41-50,age=4;51-60,age=5;≥60,age=6)	-
edu	Ordinal variable, five grades (primary school or lower ,edu=1; middle school, edu=2; high school, edu=3; college, edu=4; postgraduate and above, edu=5)	+
income	Ordinal variable, nine grades (<0.3,income=1;0.3-0.6,income=2; 0.6-1.2,income=3;1.2-2.4,income=4;2.4-3.6,income=5;3.6-4.8, income=6;4.8-6,income=7;6-12,income=8;≥12,income=9) (Unit: 10,000 CNY)	+
cog	Whether the ecological environment of the Songhua River has impact on your life, five grades (quite a lot to not at all, 5-1) Whether to care about ecological protection, five grades (quite concerned to quite ignored, 5-1) Willingness to donate for recovery of ecological environments at relatively distant place , four grades (Willing to not willing, 4-1) Extent of knowledge about ecological environments of the Songhua River, five grades (knowing quite a lot to knowing quite a little) Extent of knowledge about ecological system, five grades (knowing quite a lot to knowing quite a little)	+

We establish spatial lag model of WTP with cognition variable and social and economic attribute variables, the expression is:

$$\ln WTP = (I - \rho W)^{-1}(\beta_0 + \beta_1 male + \beta_2 age + \beta_3 edu + \beta_4 income + \beta_5 cog) \quad (13)$$

When $\rho = 0$, the model is logarithm WTP model. Matlab 2010b is used to deal with the data of double-bounded dichotomous choice CVM to make the parameter estimation respectively on the logarithm WTP function model and the spatial lag model of WTP, as shown in Table 4.

Table 4. Model Comparison

Variable	Model 1 (logarithm WTP function model)				Model 2 (WTP Spatial lag model of WTP)			
	Equation coefficient	Standard Error	*t*	*p*	Equation coefficient	Standard Error	*t*	*p*
Constant	2.3171	0.0039	16.3646	0.0000	-1.1960	0.0008	-41.7421	0.0000
male	-0.068	0.0126	-1.6498	0.0914	-0.1380	0.0083	-2.7146	0.0038
age	-0.3218	0.0048	-1.8466	0.0314	-0.2147	0.0012	-3.1178	0.0000
edu	0.5061	0.0057	2.4629	0.0000	0.5766	0.0015	10.8454	0.0000
income	0.2190	0.0032	1.9791	0.0000	0.2276	0.0005	10.7207	0.0000
cog	0.7603	0.0088	2.3988	0.0000	1.7040	0.0042	11.2962	0.0000
ρ					0.1089	0.0006	13.2962	0.0000
LogL	-1260.3				-778.7863			
AIC	1.9378				1.2015			

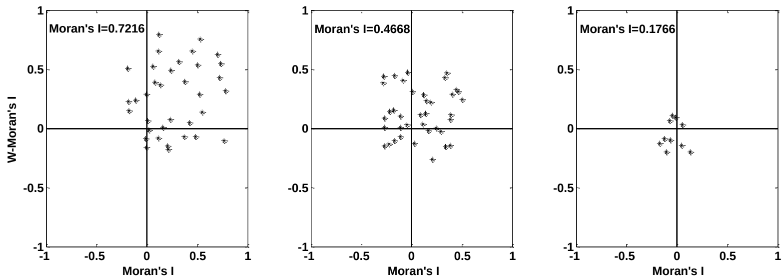
First, log likelihood value LogL and AIC criterion are taken as indicator for model selection. The Model 2 has a greater LogL value and a smaller AIC value, which means that Model 2 is superior to Model 1. Second, the variable *age* and *sex* in Model 2 are significantly increased by comparing Model 1 and negative correlation with WTP, which represents the spatial character of both variables and shows that the WTP of the young and female are more easily affected by other sub-regions. In addition, the coefficients of the cognition variable are all greater than those variables, which indicate that the effect of cognition variable on WTP is stronger and more obvious in Model 2. The cognition variable shows stronger spatial character compared with other variables. Therefore, the spatial lag model of WTP can better capture and reflect the spatial character of data and the effect on WTP compared with the logarithm WTP function model. In summary, this paper applies the estimation results of spatial lag model of WTP to make empirical analysis.

According to the estimation results, there're spatial effects among WTP. This is represented as spatial autocorrelation among regional WTP. The value of ρ is 0.1089, which is remarkably significant at 0.001. It is shown that there're spatial interaction among the overall WTP of the entire region but with small coefficients, which will be discussed further in the following two sections in this paper. The variable *sex* and *age* bear negative correlation with WTP, which indicates that the WTP of the young and the female is higher. The education variable, *income* variable and *cog* variable all bear positive correlation with WTP and are remarkably significant at 0.001, which is same as the theoretical expected effects and the coefficients are relative greater than other variables. This shows that respondents with higher educational background, greater incomes and higher degree of ecological cognition have higher WTP.

The estimation results of Model 2 in Table 4 are taken into Formula (13), the average WTP in D_1, D_2 and D_3 are respectively 241.98 CNY per year, 161.05 CNY per year and 118.17 CNY per year and the greater the distance is, the lower the WTP is, which conforms to theoretical anticipation. As shown in the 6th Census data of China in 2010, the total population in D_1, D_2 and D_3 are respectively 21963647, 15373749 and 4439339, the regional total benefit values are 5.315 billion CNY, 2.476 billion CNY and 525 million CNY. Therefore, the total benefit ecological value of Songhua River is 8.315 billion CNY.

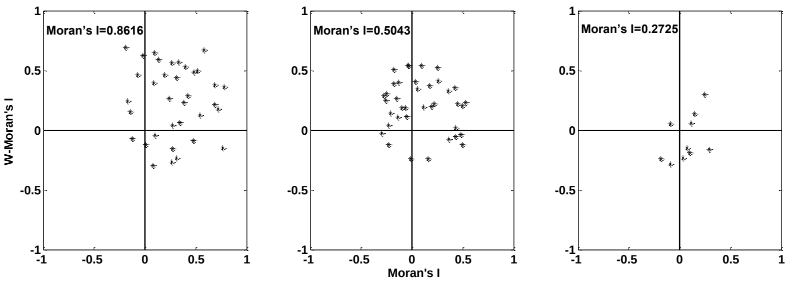
4.2. Spatial Autocorrelation of WTP

According to the results of spatial lag model of WTP, the cognition variable is provided with obvious spatial characters. Further study on the spatial autocorrelation between cognition variable and WTP are made below. To make the discussion more sufficiently, we further subdivide the prefecture-level city into county-level cities (hereinafter collectively referred to as the "County") and apply Formula (11) and Formula (12) to respectively calculate the global Moran's I Index and local Moran's I Index of the cognitive variables and WTP in counties of D_1, D_2, D_3, as shown in Figure 3 and Figure 4. The horizontal axis represents the local Moran's I Index of each county and the vertical axis represents the weighted average of local Moran's I Index of the neighbor regions around such county. According to observations from Figure 3(a) and Figure 4(a), the scattered points within D_1 are basically concentrated in the 1st Quartile and the values are all relatively greater, which indicates that a relatively high positive spatial autocorrelation both existing on cognition variable and WTP of the county and its neighbored. It's in the high value convergence status. In Figure 3(b) and 4(b), there're scattered points in each Quartile. The convergence becomes weaker and the numbers of scattered points in the 2nd quartile and 4th Quartile are increased compared within D_1, which indicates that the cognition and WTP of the county and its neighbored has relatively weakened spatial autocorrelation. However, the numbers of scattered points in the 1st Quartile are still much and in the high value convergence status. In Figure 3(c), there's no relatively strong convergence in D_3. The spatial autocorrelation is relatively weak and basically represents the independent status. In Figure 4(c) the local of the scattered points of the cognition variable represents relatively strong spatial autocorrelation and the overall spatial autocorrelation is weakened. In summary, the global Moran's I Index of WTP in each county decrease progressively, which indicates that the greater the distance is to Songhua River and the regional WTP spatial autocorrelation is weaker. The result is conforming to the research results by Hanley (2003)[12]. In addition, the spatial autocorrelation of regional cognitive degree is also weakened progressively. To this end, it may be understood that the distance decay effect of WTP is because of the spatial effect of the cognitive degree. With the increase of the distance, the spatial effect is weakened, the distance decay effect of WTP is relatively smaller and then the WTP is mainly affected by the variables of social and economic attributes.



(a) D_1 (b) D_2 (c) D_3

Figure 3. WTP Moran's I Chart of Different Regions



(a) D_1 (b) D_2 (c) D_3

Figure 4. Cognitive Moran's I Chart of Different Regions

4.3. Spatial Effect of WTP

The results of Moran's I Index show that the distance decay effect of WTP is mainly affected by the spatial effect of cognition variable. To quantify the spatial effect of the cognition variable on WTP, the parameter estimation of the cognition variable in Table 4 is taken into Formula (6) to make the spatial effect matrix $S_{cog}(W)$ of cognition variable as:

$$S_{cog}(W) = \begin{bmatrix} 1.7142 & 0.1878 & 0.0102 \\ 0.0939 & 1.7245 & 0.0939 \\ 0.0102 & 0.1878 & 1.7142 \end{bmatrix} \tag{14}$$

According to $S_{cog}(W)$, the spatial effect of regional cognition variables itself is relatively great and the spatial effects on other sub-regions decrease progressively with the increase of the spatial distance. The spatial direct effect, indirect effect and total effect of the cognition variable are acquired by Formula (8), as detailed in Table 5. The following points may be summarized according to Table 5: (1) The direct effect and indirect effect are both decreased with the increase of q and the decrease rate of direct effect is greater. (2) According to the observation of indirect effect, when $q = 2$, the value of the effect decreases sharply, which indicates that the spatial effect on WTP of the second-order neighbors begins to weaken. (3) According to the observation of Table 4, when $q = 2$, the distribution of direct effect and indirect effect of D_2 is different from that of D_1 and D_3. There are no indirect effect but direct effect within D_2.The reason is that the second-order neighbors of each sub-region involve itself and its neighbors. However, this research only involves three sub-regions. Therefore, the second-order neighbors of D_2 only involves its own and while the second-order neighbors of D_1 involves its own (direct effect) as well as D_3 sub-region (indirect effect). (4) When $q = 4$, the results of the direct effect and indirect effect is consistent with Formula (14), which indicates that the spatial effects are acquired by superposition of the effects from different order neighbors.

Table 5. Spatial Segment Effect of Cognitive Variable

q	D_1 Spatial segment Effect			D_2 Spatial segment Effect			D_3 Spatial segment Effect		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
0	1.7040	0	1.7040	1.7040	0	1.7040	1.7040	0	1.7040
1	0	0.1856	0.1856	0	0.1856	0.1856	0	0.1856	0.1856
2	0.0101	0.0101	0.0202	0.0202	0	0.0202	0.0101	0.0101	0.0202
3	0	0.0022	0.0022	0	0.0022	0.0022	0	0.0022	0.0022
4	0.0001198	0.0001198	0.0002396	0.0002396	0	0.0002396	0.0001198	0.0001198	0.0002396
Total	1.7142198	0.1980198	1.9122396	1.7244396	0.1878	1.9122396	1.7142198	0.1980198	1.9122396

Note: q is the neighbor-order.

5. Conclusion and Discussion

To explore the spatial differences among public WTP under spatial scale, EOCA method is applied to make regionalism of respondents of different distances and establish the spatial lag model of WTP. This paper discusses the relationship of spatial interaction of WTP in combination of Moran's I Index and spatial partitioned effect, which remedies the deficiency of traditional CVM model in special effect analysis. Based on the characteristic that the dichotomous choice CVM data is interval data, the probability utility function is used to propose the parameter estimation method for the spatial lag model of WTP. The CVM evaluation method of ecological values of environment goods under spatial scales is preliminary established. The research provides a new approach for CVM to evaluate the total ecological environmental benefit values and enhances the scientificity and effectiveness of CVM evaluation conclusions.

Songhua River is taken as an example to make empirical analysis for results as follows:

Comparative analysis is made between the spatial lag model of WTP and the logarithm WTP function model to prove the effectiveness of WTP spatial lag model on disposal of the data of double-bounded dichotomous choice CVM under spatial scale. The result verifies the distance decay effect of WTP and explains the fact that according to the differences of the WTP on protection of Songhua River by the respondents under spatial scale, the sharing of the cost should be different. In addition, the cognition variable represents relatively strong influence coefficient in the spatial lag model of WTP and shows the obvious characteristic of spatial data. It can be shown that the WTP of the respondents is mainly influenced by the cognition variable. In other words, the upper the cognition level of the respondents is on Songhua River, the greater the WTP is.

The Moran's I Index is applied to analyze the spatial autocorrelation between the public cognition degree and WTP among the three sub-regions. It is found that the spatial autocorrelation of WTP and the public cognition degree are simultaneously weakened progressively, which indicates that the spatial effect of WTP is affected by the spatial effect of the public cognition degree. To be specific, with the increase of the distance, the spatial effect of public cognition degree is weakened and the variables of social and economic attributes are leading to the main role on the effect of WTP.

As observed in the partitioned of the spatial effect of the cognition variable, on one hand, with the increase of the neighbor-order, the direct effect reflects relatively great decay rate and while the decay rate of the indirect effect is relatively slow, which represents the spatial effect on WTP of the spatial layout of cognition degree as well as on the indirect effect of WTP by the regional cognition degree. On the other hand, if the lag order is 2, the spatial effect decrease quickly and it is correlative with the relationship of spatial interaction coefficient ρ in the model. The greater the ρ value is, the smaller the decrease rate is. It can be shown that, if the spatial effect of cognition degree is on Order 2, the trend of decay has occurred and the spatial effect of WTP is weakened with the increase of the distance.

In 2012, the total ecological benefit value of Songhua River is 8.315 billion CNY, which shows huge non-market values. The conclusion may provide reference for the measure of resource development and protection. The drainage basin of Songhua River is with a vast territory. As restricted by labor and material, this paper only select residents in some cities and counties in Heilongjiang Province and Jilin Province covered by the drainage basin of Songhua River, which may result in uniform sample distribution under spatial scale. If the sample information may be appropriately expanded, it is believed that more accurate conclusions will be made.

To enhance public awareness of environment protection on Songhua River, efforts should be made to continuously improve the participation system of the public and to encourage local residents to join related hearings on environment protection. The participants can propose recommendations conforming to the wishes of the local residents, which can not only raise the cognition degree of the public on local environmental conditions but also enable the government to obtain more comprehensive information and policy supports by the local residents.

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