Choice modeling and its application to managing the Ejina Region, China

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Abstract

Decision-makers face a range of choices on how to manage ecosystems. Appropriate decisions should be based on weighing up the benefits and costs of alternative ecosystem management strategies, including monetary and non-monetary benefits and costs. This paper reports an application of the choice modeling (CM) method in rural China in obtaining monetary estimates of the benefits arising from changing natural resource management strategies in the Ejina Region. The application of CM is described including the goals of the study, questionnaire design and survey management. Model results were derived from 1000 in-person interviews. Significant non-monetary values were estimated for ecosystem management changes in the Ejina Region and these are useful in choosing appropriate alternative management strategies. The results indicate that improving water quality and increasing abundances of animal species were the attributes given greatest emphasis by respondents.

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1. Introduction

Ecosystem services such as the purification of water, erosion control and provision of habitat for wildlife are public goods that have value to society but no relevant market where these values are expressed (Costanza et al., 1997). The demand for estimates of non-market values, especially those associated with environmental impacts, has grown steadily over the past 20 years (Bennett and Adamowicz, 2001). With a growing public awareness of environmental issues and an increasing scarcity of environmental assets, decision-makers considering alternative uses of resources now increasingly look to include environmental values when they weigh up various resource-use options.

An important obstacle facing decision-makers in many resource-use choices is a lack of information about the value the public places on environmental impacts of human activities (Loomis and Walsh, 1997). To meet this demand, economists have developed techniques that go beyond conventional markets to estimate the value of environmental outcomes. They can be classified as either revealed-preference or stated-preference techniques (Morrison et al., 1996). The measurement of non-use values is restricted to stated-preference (SP) techniques. Among them, the contingent valuation method (CVM) is most widely used (Mitchell and Carson, 1989; Bishop and Romano, 1998). Hundreds of CVM studies have been completed in the USA and western Europe (Bishop and Romano, 1998). The CVM has been criticized frequently for its inability to provide respondents with an appropriate frame in which to consider their preferences for non-market goods, because it concentrates on the estimation of the value for one environmental good and/or one environmental condition to be changed. CM, an emerging non-market valuation technique, has potential for successful application in situations where practical issues limit the use of CVM (Bennett and Adamowicz, 2001). In contrast to the single tradeoff method of CVM, CM allows for the simultaneous analysis of several influences on choice by providing respondents with multiple choice sets. This generates more choice data and allows the estimation of more complex models of preferences.

Owing to institutional and cultural differences with western countries, Chinese research using SP technique is in its infancy. Some environmental economics appraisal methods are introduced in university courses, but they are rarely used as tools for actual government decisions. The reason for this situation is to be found in the deeply-rooted suspicion of economics by politicians and administrators: China has a centralized government and has a correspondingly centralized decision-making process as far as public expenditure is concerned. In the current stage of economic transformation from a centrally planned economy to a market economy, the Chinese people are accustomed to administered prices, not to market-determined prices. Thus, officials in China are hesitant to accept the price that people say they would pay.

In this paper, the approach of Rolfe et al. (2000) is applied to the environmental management of the Ejina Region in western China. One objective of this paper is to learn if CM can be applied in a country and culture in transition from a centrally planned economy to a market-oriented economy. Another was to estimate the non-market values of individual environmental attributes and aggregate changes in ecosystem preservation. The paper is organized as follows: Section 2 gives a general description of the Ejina Region, Section 3 shows how the CM technique operates, Sections 4 and 5 provide details of the survey design and operational aspects of the study. Section 6 presents the analysis result and finally, a brief conclusion is drawn.
2. The Ejina region

The Hei River Basin, located in the middle of the Hexi Corridor of Gansu Province, is one of the two largest inland river basins in China. Its watershed is 130,000 km$^2$ in area, its upper, middle and lower reaches stretching from the middle of Hexi corridor in Gansu to Qinghai and western Inner Mongolia. The Ejina Region lies in the lower reaches of the Hei River (between 97° 10′ 23″–103° 7′ 15″ E and 39° 52′ 20″–42° 47′ 20″ N), and is situated south of Monogoria and western Inner Mongolia (Fig. 1). It covers an overall area of 3288 km$^2$ and is surrounded by desert. With a population of 16,000 people, the Ejina Region is one of the world’s most sparsely-populated districts in the world’s most populated country.

The Ejina Region has an extreme and harsh natural environment. Its climate is characterized by frequent and severe droughts and a large seasonal temperature range. The mean annual temperature at Ejina is 8.2°C, with a maximum of 41°C (July) and a minimum of −36°C (January). Mean annual precipitation is 36.6 mm. The Hei River’s water resources are the basis of the Ejina Region’s ecology, economic development and society. Water use has grown rapidly over the past 40 years due to economic and population growth. The discharge of the Hei River at the mouth of the upstream mountain valleys at Yinluo Xia (Fig. 1) has remained at 1580 million m$^3$/yr since the 1950s. However, the flow into the lower reaches has decreased by 44.4%, from 1190 million m$^3$/yr in the 1950s to 690 million m$^3$/yr in 1995. Generally, the river stops flowing in the Ejina Region from May to July, because this is the period when irrigation extractions for agriculture are at their peak in the middle reaches of the Hei River.

The changing pattern of water use in the Ejina Region has had substantial impacts. The area of the Oasis has declined from 30,700 ha to only 3000 ha with the rest of the oasis area turning into desert. The area of degraded woodland and desert grassland has increased by 350,900 ha since 1960. Surveys have shown that of the 112 animal species found in the Ejina Region in 1960, 93 remain in 1995. The declining water quality has affected living standards of the residents. Sandstorms have increased recently in the middle reaches of the Hei River (AIGW, 1996; Wang and Cheng, 1999).

The Ejina Region is the first barrier to sandstorms originating in northwestern China, and its deterioration has an influence on much of north China (see Xu et al., 2003 for a detailed description). As a result, the government and the Hei River Management Bureau decided to adopt some measures to preserve and manage the Ejina Region. Because of the many attributes of the system, there are many potential management options. Such measures as planting trees and grasses, enclosure of pasture, and building reservoirs were taken to increase the oasis area, curb soil erosion, purify water and to reverse land desertification.

With a view to curbing desertification, the decision-makers have mainly paid attention to the oasis area. Because water flow from the middle reaches of the Hei River has gradually decreased, maintaining its existing area has been difficult. In addition, conflicts over how to allocate water resources between the middle reach of the Hei River and Ejina have greatly increased since 1980. At the same time, overgrazing predominantly of sheep is widespread in the Ejina Region.

3. The choice modeling technique

To decision makers faced with a range of potential ecological improvement or protection strategies, the problem is which options to choose. To assist in such choices,
Fig. 1. Diagrammatic study area and sampling sites and sample sizes (given in parentheses with sampling site).
decision makers may seek quantification, in money terms, of the benefits and costs their choices will have on society. CM can assist in providing estimates of environmental values that are otherwise unavailable through market observation. By varying the levels of the environmental attributes of the management alternatives presented to the respondents in a CM application, the analyst can collect a wealth of information on the willingness of respondents to make trade-offs between the individual attributes and their likely responses to different scenarios. With respondents’ preferences broken down into components associated with environmental attributes, it is possible to use CM results to investigate the relative importance of the various attributes and estimate the benefits associated with various combinations of attributes levels.

CM is based on random utility theory (RUT) which suggests that consumers seek to maximize utility when they make choices. RUT holds that there is a deterministic or observable component (systematic) and a random or unobserved (error) component of utility ($U_{ij}$). The following equation formalizes the basic relationship where $V_{ij}$ denotes the measurable component of utility and $e_{ij}$ represents the effect of unobserved and random influences on choice for respondent $i$ and choice option $j$.

$$U_{ij} = V_{ij} + e_{ij}. \quad (1)$$

Taking the characteristics of relevant goods ($Z_{ij}$) and the respondents ($S_i$) into account the utility function can be deduced from the following Eq. (2):

$$U_{ij} = V(Z_{ij}, S_i) + e_{ij}, \quad (2)$$

where $V$ is the indirect utility function.

In addition, the probability that a respondent $i$ will choose option $j$ from the set of choices $C$ is higher than other alternatives $h$, as in

$$P_{ij} = \text{Prob}(V_{ij} + e_{ij} > V_{ij} + e_{ih}) \quad \text{(for all } h \text{ in the choice set } C, j \neq h). \quad (3)$$

Estimation of choice probabilities is via a multinomial logit (MNL) model with the following form, where $V$ represents the systematic component of the utility of an alternative, and $\lambda$ is a scale parameter which is commonly normalized to 1:

$$P_{ij} = \frac{\exp(\lambda V_{ij})}{\sum \exp(\lambda V_{ij})} \quad \text{(for all } h \text{ in the choice set } C). \quad (4)$$

The MNL model relies on the assumption of the independence of irrelevant alternatives (IIA). The IIA arises from the assumption about the independence and identical distribution (IID) of the error term. IID of error term means that it has an extreme value error distribution. The IIA means that the probability of choosing an alternative is dependent only on the options from which a choice is made, and not on any other options that may exist. If the IIA/IID is violated, the estimates derived from the model could be biased and not generate accurate values for inclusion in cost benefit analysis (Ben-Akiva and Lerman, 1985).

There are various reasons why IIA/IID violation could be occurred. One possibility is the existence of random taste variations (that is heterogeneity). To account for this, a model which includes socioeconomic variables in addition to the attributes in the choice sets can be estimated (Bennett et al., 2001). The socio-economic information could be included in two different ways. The first is by interactions with the attributes in the choice sets. The second method includes the socio-economic information through interactions.
with the alternative specific constants. These interactions show the effect of various socio-
economic characteristics on the probability that a respondent will choose particular
options.

The structure of the MNL model depends on the form of the indirect utility function. An
additive indirect utility function can be used to estimate main effects:

$$V_{ij} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + \cdots + \beta_n Z_n + \beta_a S_1 + \beta_b S_2 + \cdots + \beta_m S_j,$$

where $\beta$ is the constant term, and $\beta_1$ to $\beta_n$ are the vectors of coefficients attached to
the vector of attributes ($Z$) that influence utility, and $\beta_a$ to $\beta_m$ are vectors of coefficients
attached to the vector of socioeconomic characteristics of respondents. The constant term
$\beta$ can be taken as a vector of alternate specific constants (ASCs) unique for each of the
alternatives that are considered in the choice sets. These ASCs capture the influence on
choice of unobserved attributes relative to specific alternatives.

The marginal value of a change within a single attribute is represented as a ratio of $\beta$
coefficients. Eq. (6) displays a part-worth formula: for the amount of money respondents
are willing to pay in order to receive one unit more of the non-marketed environmental
attribute (Bennett and Adamowicz, 2001):

$$W = -1[\beta_{\text{non-marketed attribute}}/\beta_{\text{money attribute}}].$$

From Eq. (6), the implicit prices ($W$) for the various environmental attributes can be
calculated. These demonstrate the amounts of money that respondents are willing to pay in
order to receive more of the non-marketed environmental attributes.

Implicit prices are not estimates of compensating surplus of the type required for use in
benefit–cost analysis. They are ceteris paribus estimates of the value of a change in only
one attribute. Estimating the overall willingness to pay for changes from the current
situation requires further calculations by Eq. (7). This is because multiple attribute changes
are involved and because the attributes in the choice sets do not capture all the influences
on value. To estimate overall willingness to pay it is necessary to include the alternative
specific constant.

Welfare estimates can be estimated from MNL models through the use of the following
formula:

$$CS = \frac{-1}{\alpha [\ln \sum \exp V_{i0} - \ln \sum \exp V_{i1}]}.$$

where $CS$ is the compensating surplus welfare measure, $\alpha$ is the marginal utility of
income (generally represented by the coefficient for the monetary opportunity cost
attribute in an experiment), $V_{i0}$ and $V_{i1}$ indicate indirect utility functions of alternative $i$
with subscript 0 indicating the base situation and 1 indicating the changed situation under
consideration.

4. Survey design

To apply the CM technique to the case of the Ejina Region, a questionnaire was
developed using the results from three focus groups and a pre-test involving 29
interviewees. Each focus group consisted of 8–10 local residents. Participants were
required to be older than 18 years and to have obtained a high school diploma, so that they
would have enough knowledge to make appropriate trade-off choices. With a view to
increasing participants’ interest, a payment (CNY 2\(^1\) per participant) was mentioned after the person agreed to attend. The focus groups were given three tasks, namely attribute selection, assessment of the information required by respondents to answer the choice questions and tests of questionnaire design.

A number of possible attributes were identified in the focus group stages. These were condensed to five possible attributes, namely cultivated area, water quality, animal species, animal abundance and a one-off levy on income. The level across which each attribute could vary reflected the broad possible range of ecosystem management options in the Ejina Region. The levels of the early 1980s were used as the upper limits of area, water quality and numbers of animal species. Levels of attributes pertaining to the ecosystem as it is now were used as the lower limits. The upper limit of animal abundance was based on figures (mainly sheep number) from the 10 year development plan for the Ejina Region. By fusing the outcome of a previous CVM analysis (Xu et al., 2003) and the suggestions of the focus groups, CNY 200 was used as the cost attribute’s upper limit, and it was assumed that there was no levy for the current situation. The attributes and their alternative levels are displayed in Table 1.

The payment vehicle was presented as a one-off payment to preserve and restore the Ejina ecosystem. Interviewers told respondents that they could select their preferred method of payment such as an ecological protection tax, or working for the project in lieu of payment. This was to overcome the problem of non-acceptance of a pre-specified payment vehicle.

The choice sets are the heart of the CM questionnaire. During the focus groups, it was found that the trade-offs introduced in the choice set were difficult for respondents to understand. To limit the cognitive burden on respondents, a representative sample of the distribution of possible scenarios was generated. The five attributes varying across three levels could be combined in \(3^5\) ways to form 243 possible different profiles of ecosystem management (Bennett and Adamowicz, 2001). An experimental design process was used to select the set of five choice set profiles that were presented to each survey respondent. An example of one of the choice sets used in the survey is set out in Table 2.

The questionnaire comprised three parts. The cover and first section of the survey provided a series of maps to inform respondents where the Ejina Region is located and the condition of its ecosystem. The respondents were told that their answers would be used as input to the government in its upcoming project to manage the Ejina Region. It was explained that protecting the Ejina ecosystem would have some positive influence on living conditions of valley residents, including (1) controlling soil erosion and reducing

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\(^1\)USD = CNY 8.3 (China Internet Information Centre, 2006).

<table>
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<th>Attributes and their levels used in empirical study</th>
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<tr>
<td>One-off levy on income (yuan)</td>
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<td>Current situation</td>
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sandstorms, (2) providing habitat for wildlife, (3) natural purification of water, and (4) curbing land salinization. The current state of the ecosystem and current management methods were described and illustrated in detail. The means by which the ecosystem could be restored were also described. The second part introduced the choice sets. Before asking respondents to make choices among various choice options, a simple example was used to explain the trade-offs involved. It was emphasized that no support for any change would mean that the Ejina ecosystem would continue to deteriorate. As the final part, a series of personal questions, aimed at obtaining respondents’ socio-economic information was included.

5. Survey implementation

5.1. Survey process and sample selection

The sampling frame used included households living within the Hei Valley. It is in this valley that the deterioration of the Ejina ecosystem originates. A random sample of these households was selected. In-person interviews of 1000 from the total 483,223 households in the valley were carried out during July 2002. To identify households for sampling, two processes were used. Firstly, random digit dialing was used in cities and towns that have telecommunication networks to choose 457 households. Secondly, in regions that had no telephones, the names of the heads of households were collected and recorded. Then a random drawing of household names was used to choose a total of 543 households. The detailed sampling sites and sample sizes are shown in Fig. 1. The initial contact phase of the survey took specific measures to adapt the process to the Chinese social context. Potential respondents were approached and given a brief explanation of the general topic of the survey. They were then asked to complete an in-depth, in-person interview at an appointed time. With a view to increasing the response rate, an official, personally signed letter of invitation was provided. In addition, a CNY 2 bill was presented as a token of appreciation at the start of the interview. In selecting respondents, requirement was stipulated that they had to be over 18 years of age with at least a high school diploma. This strategy was used to ensure that respondents would have enough knowledge of the household values and choice experience with respect to purchasing commodities to be able to answer the questionnaire in a meaningful way.

The in-person interviews resulted in a response rate of 995 out of the 1000 questionnaires distributed. Another feature of the interview process that was developed to reflect the
Chinese social context was that in addition to the selected respondent, friends and family frequently waited around the interview room expressing interest in the questions.

Among the collected questionnaires, six were incomplete and were omitted. In total, the survey produced a total of 4709 choice observations from 989 respondents.

5.2. Characteristics of the respondents

In the third part of the questionnaire, respondents’ demographic data were collected. About 22% of the respondents were within the range 18–24 years old. The most frequent age class was 25–35 years (48.6%). Around 23.2% and 6.0% of the cases fell within the age-ranges 36–50 and > 50 years, respectively. The average age of respondents was just above 33 years. Twenty-five per cent of the respondents had a high school diploma, 33% having attended a university for 3–4 years and 12% of the interviewees possessing a Junior Certificate. Such relatively high education levels may be attributed to the household members selecting an individual who had highest level of education to answer on their behalf. The most frequent family annual income bracket was below CNY 5000 (23%); 25% indicated the range of CNY 5000–10,000/yr, 31% the bracket CNY 10,000–20,000/yr, and 18% above CNY 20,000/yr. Sixty-two per cent of the respondents were male. In terms of domicile class, around 60% of respondents lived in urban areas.

6. Modeling the data

Two different multinomial logit (MNL) models were estimated using the data from the Hei River survey. The analysis was undertaken using LIMDEP, a specialist discrete choice modeling package (Greene, 1998). The first was a basic model that showed the importance of choice set attributes in explaining respondents’ choices. The second model included socio-economic variables in addition to the attributes in the choice sets.

In the basic model (Table 3), all attributes in the model were statistically significant at the 5% level, and their signs were as expected a priori. The negative sign for the animal numbers attribute indicated that increasing sheep numbers decreases utility, possibly because of the increased water stress in the middle reaches of the Hei River that would result.

The results indicate that the indirect utility function took the following form:

\[
V_{ij} = 0.3147 - 0.0074(Z_{\text{cost}}) + 0.0014(Z_{\text{oasis area}}) + 0.2011(Z_{\text{water quality}}) \\
+ 0.1119(Z_{\text{animal species}}) - 0.1616(Z_{\text{animal number}}). \tag{8}
\]

The IIA tests performed indicated that the model did not fully conform to the underlying IIA/IID assumption. While the IIA/IID assumption was not violated when the ‘no choice alternative’ was dropped (Rolfe et al., 2000), they were \(\chi^2 = 6.45\) when the second alternative was dropped from the choice set.

To address the violation, the second model included socio-economic data in addition to the attributes in the choice sets (Table 4). This specification of the model was significantly different from the previous specification (Table 3). In particular, the model had a higher level of parametric fit compared with the first model \(\chi^2 = 348, p < 0.01\). The improvement in model fit was significant.
From the results of the second model (Table 4), the implicit price for the various non-marketed attributes can be calculated. For the qualitative attribute water quality, ‘bad’ was used as a base level, thus setting its coefficient in the resulting model to zero. Positive coefficients for the other levels of water quality indicate that respondents preferred to move away from the bad level of water quality. Respondents were willing to pay CNY 0.22 for an increase of 1 km² in cultivated area and CNY 6.09 for the addition of one animal species (Table 5). The use of qualitative, discrete levels for the water quality attribute meant that on average each respondent household valued an improvement in water quality from ‘bad’ to ‘general’ at CNY 20.04, to ‘good’ at CNY 20.67 and to ‘better’ at CNY 38.83. Respondents on average needed to accept CNY 7.11 as their compensation for increasing the number of animals by 10,000.

Estimates of willingness to pay were calculated for seven alternative scenarios in choice sets (scenario 1–7) (Table 6). To illustrate this process, for example, the difference between the current situation and scenario 1 can be represented as
The CS value indicates that the value attached to scenario 1 was CNY 110.43. That is, the average willingness to pay per household in the Hei River for an improvement in ecological conditions from the current situation to scenario 1 was 110.43 yuan. These per household estimates can be extrapolated to estimate the whole Valley’s willingness to pay to achieve the six scenarios of improved ecological condition in the Hei River region.

In the case-study of the Ejina Region, the analysis of implicit price means that respondents’ preferences were focused on improving water quality and increasing animal species. The modeling results can also be used to estimate values associated with a range of scenarios resulting from different ecosystem management practices. Government managers can use these value estimates, and estimates of the value of any change in oasis area, water quality, animal species and animal abundance to determine which scenarios are likely to have the greatest net benefit for the community. From the empirical analysis, scenario 7 produced the highest willingness to pay (CNY 293 per household). Aggregate willingness to pay can be compared to aggregate costs in a cost–benefit analysis framework to assess...
whether the people of the Hei River are likely to experience a net benefit from proposed change to management.

7. Conclusions

The economic surplus of changing ecosystem condition is important information for decision makers considering the consequences of changes in the condition or quality of an ecosystem. The valuation process reduces multi-attribute information to a single number. This can make the results achieved from change easier for the decision maker to consider. Choice modeling is one developing non-market valuation technique that has potential for this purpose. A recent application of the technique to ecosystem management is reported here.

Three conclusions can be drawn from this study. First, owing to institutional and cultural differences with western developed countries, some Chinese policy makers are suspicious of whether non-market valuation techniques like CVM and CM can be applied in China. This CM study has demonstrated that carefully designed and pre-tested non-market valuation techniques can be applied in China. Second, the study illustrates that there is a positive willingness to pay for various improved ecosystem conditions in the Hei River. The CM technique can be used to model a variety of simultaneous tradeoffs which involve a mixture of environmental and socio-economic factors. The results provide a tool for decision makers to use in prioritizing ecosystem management options. Finally, the application of CM appear promising by its potential to model complex and simultaneous tradeoff in the field of ecological management.

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