Choice Modelling as a tool of Environmental Decision Making

Prof Jeff Bennett
Australian National University
Workshop Programme

- 12.30 - 13.00  What is Choice Modelling?
- 13.00 - 14.00  How do you do it?
- 14.00 - 15.00  Some recent Australian applications
- 15.00 - 15.30  Afternoon tea
- 15.30 - 16.30  Using Choice Modelling in Environmental Decision Making
1. What is Choice Modelling
Some scenarios ...

• Drain a wetland for agricultural development or declare it a protected area?
• Allow an increase in water diversions for irrigated cropping or increase environmental flows across a river basin?
• What is the appropriate level to cap SO2 emissions from a power station?
• Should more tax revenue be spent on health or the environment?
Choices ...

• All scenarios involve choices
• All choices involve trade-offs
  – wetland bird life or agricultural crops
  – fish species or irrigation profits
  – clean air or electricity
  – more hospitals or more nature reserves
• Decision making is about assessing those trade-offs
Markets or not?

• Society makes most of its choices in markets:
  – to use land to produce milk or kiwi fruit
  – to work as an engineer or a lawyer
  – to buy a new car or an apartment

• When significant environmental impacts are involved in decisions, markets can be inadequate.
Where to without markets?

- When the *decentralised* operation of markets fails to deliver environmental goals, governments have stepped in with *centralised* decision making.
- This too can be problematic.
- Information on the relative value of the choice alternatives is critical to the assessment of the trade-offs.
Valuation options

• Without markets to provide value estimates, need to look at “non-market” valuation techniques.

• Two types:
  – Revealed preference methods
  – Stated preference methods
Revealed preference methods

• Use relationships between non-marketed goods and services and markets

• Hedonic Pricing Method:
  – where non-marketed element influences the price of a marketed good

• Travel Cost Method:
  – where spending on travel is used to infer the value of a non-marketed recreational site
… or stated preference methods

- Revealed preference methods are limited:
  - must be related to markets
  - are retrospective
- Stated preference methods are not so limited because they involve asking people questions about their preferences for potential changes.
Contingent Valuation Method

• The best known stated preference method is the contingent valuation method (CVM).

• A sample of people asked:
  – how much are you willing to pay to secure (or avoid) a proposed environmental change? OR
  – would you pay $x to secure (or avoid) a proposed environmental change?
### Dichotomous choice CVM

<table>
<thead>
<tr>
<th></th>
<th>Status Quo</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species (#)</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>Tourists (000 pa)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
CVM problems

• Controversial especially after the Exxon Valdez case
• Concerns regarding potential biases
  – strategic
  – framing
  – hypothetical
• Expensive
An alternative?

• Search for improvement led to Choice Modelling.

• Originally developed in the marketing literature as a type of “conjoint analysis” to estimate the likely impact of a new product.

• Adapted by transport economists to predict modal mixes when a new form of transport is introduced.
Choice Modelling

• A sample of people are asked to indicate their preferred option from an array of possible alternatives- which includes the status quo.

• Similar to CVM except that:
  – can be more than two alternatives
  – each respondent is asked to make more than one choice
Some jargon

• Each choice question is called a “choice set”.

• Each alternative is described in terms of a common set of “attributes”.

• Alternatives are differentiated by the “levels” taken on by the attributes.
### A choice set

<table>
<thead>
<tr>
<th></th>
<th>Status quo</th>
<th>Alt. A</th>
<th>Alt. B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td>5</td>
<td>8</td>
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</tr>
<tr>
<td><strong>Cost ($)</strong></td>
<td>0</td>
<td>100</td>
<td>150</td>
</tr>
</tbody>
</table>
Targeted choices

• The sequence of choice sets are created using an “experimental design” so that respondents make choices across the full range of possible combinations of attribute levels.

• Respondents’ choices demonstrate their willingness to trade-off between the various attributes.
Value estimates

• Given that money is the unit used to measure one of the attributes, it's possible to infer from the choices made, the willingness to pay to secure increases in the non-monetary attributes - *implicit prices*.

• Also possible to estimate the monetary value of a change from the status quo to a new combination of attribute levels - *compensating surplus*.
Some advantages ...

• A rich data set: attribute values and compensating surpluses.
• Flexibility = cost effectiveness.
• Benefit transfer potential
• Strategic bias reduction
• Framing effect control
… and some negatives

• Still hypothetical (but possibly less so).
• Cognitive limitations of respondents may be stretched.
• Analytical complexity
2. How do you do it?
Step 1. Establish the issue

• Consistent with BCA principles.
• Change from the status quo (current or future) - at the margin.
• Define the value to be estimated - use or non-use values; total economic value?
• Define the context around the value to be estimated.
Step 2: Structure the research design

• Methodological sensitivities?
  – Presence/absence of an attribute?
  – Significance of some information?
  – Payment vehicle?

• Geographic extent?
  – Do values vary across space?

• Need separate versions of the questionnaire for sub-samples of the population
Step 3: Define the attributes ...

- Alternatives that create the values sought are described by the attributes.

- Two perspectives:
  - "supply": the views of the policy maker need to be reflected in the selection of attributes - they need to be "policy relevant"
  - "demand": those who will answer the choice sets must find the attributes relevant and comprehensible
by ....

- Surveying decision makers (informally or formally)
- Surveying prospective respondents
- Focus groups
  - “what information do you need to know before making choices about the future?”
  - “what are the good and bad things about potential outcomes?”
... but beware

• Too many attributes.

• Causally prior attributes:
  – “indicator” attributes can be a focus for respondents and dilute the relevance of other attributes.

• Collinear attributes:
  – where attributes are perceived to be dependent on each other, experimental design driven variations can cause confusion.
Step 4: Setting the levels

• Presentation options:
  – qualitative (good, fair, bad)
  – quantitative (absolute or marginal)

• The range:
  – realistic to projected future policy changes
  – payment maximum discussed in focus groups

• The interval:
  – avoid excessive numbers of levels
Step 5: Design the questionnaire

• Determine the mode of delivery:
  – personal interview
  – drop-off/pick-up
  – telephone
  – mail-out/mail-back

• This will set some benchmarks for the questionnaire design eg the use of visual aids.
5.1 An introduction

• An accompanying letter or a preface detailing:
  – Purpose of the questionnaire
  – Who is doing the study (credentials)?
  – How respondents were selected?
  – How to raise queries?
  – Confidentiality assurance
  – Instructions on how to complete
  – Thanks
5.2 The “frame”

• Respondents must be made aware that the non-marketed good in question is embedded in an array of substitute and complementary goods.

• The issue needs to be *framed* in a manner consistent with the policy decision.

• Eg … rank competing issues.
5.3 The issue

• Describe the problem:
  – Describe the current conditions and what will happen without change

• Use an information brochure

• Avoid biased presentations - check with proponents of change and the status quo
5.4 The solution

- Outline potential scenarios of changes that could be implemented to avoid the status quo. Focus on change.
- Avoid biased information.
- Introduce the payment vehicle (the cost attribute) - plausibility is critical.
- Payment will be compulsory.
5.5 Introduce the choice sets

- Explain the task ahead
- “Many ways to approach the problem with many different outcomes” helps to explain the multiple choices arising from the experimental design.
- Framing reminder, especially on the budget constraint.
- Give an example.
5.6 The choice sets

- Clarity is key - use focus groups to check.
- Generic or labelled?
- Number of alternatives?
- Horizontal or vertical?
- Pictographs or numbers?
- etc
5.7 Follow up questions

• Look out for anomalies:
  – payment vehicle protests
  – lexicographic preferences
  – perfect embedding
  – confusion levels
  – perceptions of bias in the information
  – assessment of plausibility
5.8 Socio economics

- To determine if the sample is representative and to check for influences on choice behaviour, ask for:
  - age,
  - gender,
  - income,
  - educational level
  - and attitudes
Step 6: Compile the experimental design

• CM relies on observing respondents’ choices when faced with an array of different alternatives.

• The probability of an attribute being selected is modelled as a function of attribute levels.

• This requires respondents being exposed to the full range of attribute level combinations.
Factorials

• The complete set of possible combinations is called the “full-factorial”
  – 2 attributes, 3 levels = $3^2$ combinations = 9
  – 4 attributes, 3 levels = $3^4$ combinations = 81
    for just one alternative

• Too many choices!
Fractions

• An “experimental design” selects a fraction of the full factorial that is “representative”.
• The fraction is sufficient to provide for statistically robust modelling whilst limiting the burden placed on respondents.
• May still need “blocking”
• And will require combining into sets of alternatives
7. Survey the respondents

• Select the sampling frame for the relevant population.

• Draw the sample to reflect the research design (sub-samples) and the blocking:
  – different versions of the questionnaire will require different sub-samples.

• Beware of sampling and interviewer bias.
8. Prepare the data

- Each choice alternative yields one row of data.
- Each row is a set of attribute levels for an alternative, a set of socio-economic data for the respondent making the choice AND a yes/no choice.
- Add in an “alternative specific constant” to take up any unexplained variation.
9. Analyse the data

- Most straightforward modelling of choices uses “Multi-Nominal Logit” procedure.
- The log of the odds of an alternative being chosen is explained by the levels of the attributes in the alternative and the socio-economic characteristics of the respondents.
- The equations so estimated are interpreted as the indirect conditional utility from an alternative.
Utility functions

• For a three attribute, generic choice set:

  • SQ: \( V_1 = \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 \)
  • Alt 2: \( V_2 = \text{ASC} + \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 \)
  • Alt 3: \( V_3 = \text{ASC} + \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 \)

  – where the \( \beta \) values are the coefficients of the three attributes (A)
Complexities

• Heterogeneity of respondents addressed by interacting socio-economic characteristics with ASC or attributes

• Non-linearities

• Nested logit models

• Assess models by their logic, significance of the explanatory variables and McFadden’s $R^2$ (between .2 and .4)
10. Analyse the results

- Implicit prices (Part worths or attribute values) are the marginal rate of substitution between the monetary attribute and the non-monetary attributes.
- Willingness to give up money to have more of the non-monetary attribute (ceteris paribus)
- Implicit price = - (β_{NMA} / β_\$)
… for qualitative variables

• Each level of qualitative attributes has a separate $\beta$ coefficient.

• The difference between $\beta$ coefficients for different levels, divided by the monetary attribute $\beta$ yields an estimate for the value of a change from one level to the other (e.g. the value of improving water quality from poor to good).
...but...

- Beware comparing attribute values without consideration of the units involved (e.g., the value of an additional species protected vs the value of an additional tourist visit)
- These are estimates of gross benefit and do not reflect the costs of supply.
Compensating surplus

• CM can yield estimates of values of many different alternatives (relative to the status quo) from the one application

• \( CS = -\left(\frac{1}{\beta} \right) (V_{SQ} - V_X) \)

• The values for \( V \) are estimated by substituting into the equations with the levels of the attributes for the SQ and the alternative “X”.
3. Recent Australian Applications
The selection

• *Remnant vegetation in Central Queensland*
  – Tree clearing for beef cattle grazing vs biodiversity protection

• *Rivers in New South Wales*
  – Diversion of water for irrigated agriculture vs environmental flows for river health

• *Land and water degradation*
  – A generic analysis for policy making at a range of levels
1. Remnant vegetation protection

- The Desert Uplands
  - pastoral land of relatively low productivity
  - integrity of most ecosystems in the region remains high
  - subject to development pressure that involves mass clearing of remnant vegetation

- Queensland Government must approve all applications to clear - information required to assess the trade-offs
The choice set

• Three alternatives including Status Quo
• 6 attributes:
  – Levy on income tax
  – Loss in area of unique ecosystems
  – Number of endangered species
  – Reduction in the pop. of non-threatened species
  – Income lost to the region
  – Jobs lost in the region
The survey and results

- 480 Brisbane households
- Drop-off/pick-up delivery
- Modelled using nested logit
  - two stage choice process:
    - change vs no change
    - change option 1 vs change option 2
- Attributes significant at the 1% level
- McFadden’s $R^2$ of 20%
## Implicit prices

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Implicit price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endangered species</td>
<td>11.39</td>
</tr>
<tr>
<td>Non-threatened species (per %)</td>
<td>1.69</td>
</tr>
<tr>
<td>Unique ecosystem (per %)</td>
<td>3.68</td>
</tr>
<tr>
<td>Jobs lost</td>
<td>3.04</td>
</tr>
<tr>
<td>Regional income ($m lost)</td>
<td>5.60</td>
</tr>
</tbody>
</table>
Compensating surpluses

• The benefit from
  – 2 additional species
  – an extra 30% non-threatened species protected
  – an extra 10% area of unique ecosystems protected
  – 10 jobs lost
  – $5m regional income lost
  averages $76 per household (one-off payment)
Offsetting losses

- Jobs and income attribute values offset the benefits of nature protection … without those losses, the benefit is $87 per household.
- There would be no benefit if 180 jobs were lost and $10m of regional income was lost.
2. **Environmental flows**

- Water reform in NSW requires assessment of alternative flow regimes by catchment management committees.
- Trade-offs between irrigation earnings and environmental values.
- Prospect of using CM results for benefit transfer across the State’s rivers.
Research design

• Selected five rivers to “represent” the spectrum of rivers across the state
• Selected four “generic” environmental attributes of rivers:
  – water quality as represented by recreational activities
  – healthy riverside vegetation
  – Native fish species
  – Water bird and other fauna species
Samples

- Samples of people drawn from those living within all the catchments and some living outside.
- A further questionnaire designed to estimate environmental values across ALL the state’s rivers (framing).
- Eight sub-samples of 900 people drawn.
The survey

• Mail-out/mail-back format
• Four stage surveying process
• 38% overall response rate
• Some self-selection favouring older, wealthier, better educated male respondents
<table>
<thead>
<tr>
<th></th>
<th>Veg</th>
<th>Fish</th>
<th>Bird</th>
<th>WQ1</th>
<th>WQ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEG</td>
<td>2.32</td>
<td>7.37</td>
<td>0.92</td>
<td>53.16</td>
<td>50.14</td>
</tr>
<tr>
<td>CLA</td>
<td>2.02</td>
<td>0.08*</td>
<td>1.86</td>
<td>47.92</td>
<td>24.73</td>
</tr>
<tr>
<td>GEO</td>
<td>1.51</td>
<td>2.11</td>
<td>0.67*</td>
<td>48.19</td>
<td>27.28</td>
</tr>
<tr>
<td>MUR</td>
<td>1.45</td>
<td>2.58</td>
<td>1.59</td>
<td>53.43</td>
<td>20.35</td>
</tr>
<tr>
<td>GWY</td>
<td>1.49</td>
<td>2.36</td>
<td>1.89</td>
<td>51.31</td>
<td>60.21</td>
</tr>
</tbody>
</table>

Value estimates: within
Value estimates: outside

<table>
<thead>
<tr>
<th></th>
<th>Veg</th>
<th>Fish</th>
<th>Bird</th>
<th>WQ1</th>
<th>WQ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUR</td>
<td>2.17</td>
<td>3.81</td>
<td>1.80</td>
<td>30.50</td>
<td>60.68</td>
</tr>
<tr>
<td>GWY</td>
<td>2.01</td>
<td>3.43</td>
<td>0.55*</td>
<td>29.19</td>
<td>30.35</td>
</tr>
</tbody>
</table>
Interpreting the estimates

- Implicit prices or attribute values.
- eg On average respondent households in the Bega River valley value the presence of an additional fish specie in the river at $7.37.
- Water quality is a qualitative attribute
- WQ1 relates to improvements along the length of the river from boatable to fishable
- WQ2 is fishable to swimmable
and so ...

- On average, each respondent household values an improvement in Clarence River water quality that would make it safe for fishing along the length of the river at $47.92.

- This value needs to be adjusted if the changes affect less than the whole length of the river.
and note that ...

- Direct use value estimates tend to be larger for within catchment respondents.
- Non-use value estimates are larger for the outside catchment samples.
- Within catchment value estimates are predominantly different across the rivers.
- Hence … not a one-size-fits-all situation.
Benefit transfer

• Use the value estimates generated
  – for the specific catchments and
  – the specific group of beneficiaries
  in the CM exercise

… to approximate the values for other catchments and other groups of beneficiaries.
A BT Model

• For cases where a relevant value has not been estimated (e.g., a coastal river and an outside catchment population OR an insignificant value estimate)
  – use the value estimates generated by a benefit transfer model

\[ V = v \cdot (\text{North/South, Coast/Inland, Inside/Outside catchment}) \]
Framing

• Expect the values held by outside catchment residents for one river would be greater than if multiple rivers were being valued.
• Respondents regard rivers as substitutes and subject to diminishing marginal utility PLUS limited budget.
• With more rivers, the per river value would be lower.
State-wide estimates

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value ($ per h/hold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>4.23</td>
</tr>
<tr>
<td>Fish</td>
<td>7.70</td>
</tr>
<tr>
<td>Fauna</td>
<td>2.37</td>
</tr>
<tr>
<td>WQ: fishable</td>
<td>44.05</td>
</tr>
<tr>
<td>WQ: swimmable</td>
<td>87.17</td>
</tr>
</tbody>
</table>
Implications

- State-wide values are greater than single rivers
  \textbf{BUT}
- using the single river values estimates across multiple catchments may cause upward bias.
- Need to be aware of the policy context to create the appropriate valuation frame.
Aggregate value estimates

• Extrapolate across the sample fraction (plus 1/3 of non-respondents)
• Aggregate using attribute values where attribute changes are small.
• Aggregate using compensating surplus method where attribute changes are large.
Some examples

• South coast river: Veg +5%, Fish +2, Fishable for 15% of river
  – Value = $32m

• For the state: Veg +10%, Fish +5, Bird +23, 15% swimmable
  – Value = $162.9m
3. Land and water degradation

• Land and Water Resources Audit
• To estimate values for a set of generic environmental and social attributes associated with land and water resources degradation policies.
• Establish a base for benefit transfer.
Research design

• Values estimated for three contexts:
  – National
  – Fitzroy Basin region
  – Great Southern region

• Values established for three populations:
  – Regional centre
  – Capital city
  – National
Attributes

• Endangered native species
  – # species protected from extinction

• Countryside aesthetics
  – Ha. of farmland repaired or bush protected

• Water way health
  – Km of waterways restored for fishing and swimming
Attributes cont.

- Country communities
  - The net loss p.a. of people from country towns.

- Environmental levy
  - $ annual household income tax levy for 20 years
The survey

- Mail-out/mail-back (with reminder letter and remail)
- 10,800 households sampled from the populations national + two regional centres plus two capital cities
- 16% response rate
### National results

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Unit</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>$ / species</td>
<td>0.68</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>$ / 10,000 ha</td>
<td>0.07</td>
</tr>
<tr>
<td>Waterways</td>
<td>$ / 10 km</td>
<td>0.08</td>
</tr>
<tr>
<td>Country com.</td>
<td>$ / 10 people</td>
<td>-0.09</td>
</tr>
</tbody>
</table>
Benefit transfer tests

• Test if the national estimates can simply be transferred to regional contexts:
  – National values are lower than values of regional populations for regional cases.

• Are the attributes viewed the same by differing populations?
  – Regional differences do exist eg social impacts are values more highly in Queensland than WA.
More tests

• Framing test: Respondents have significantly higher values when attributes are framed in the regional rather than national context.

• Population differences: City and Regional populations hold equivalent values
Conclusions

• Household values estimated at the national level should be scaled up if used in a regional context.

• Value estimates for regional changes have a “geographic extent” beyond the immediate region. Aggregation exercises need to take this into account.