Estimating the Values of Environmental Impacts of Agriculture*

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Abstract

Assessing the sustainability of agricultural enterprises requires an evaluation of environmental impacts. It is argued that this evaluation must extend beyond the biophysical to incorporate an estimation of the value people have for those impacts. Two case studies involving the impacts of irrigation on wetlands in New South Wales and tree clearing for cattle grazing in Queensland are presented to demonstrate the capabilities of Choice Modelling to generate dollar estimates of environmental values.

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1. Background

One of the consequences of modern agricultural activity is the modification of the natural environment. The introduction of non-native species of plants and animals and the management of the environment to ensure their successful growth and reproduction has meant the displacement of the original ecosystems.

The ecosystems that have been created yield significant benefits to the community. They provide products - beef, cotton, wool, rice, wheat etc -that are valued by society. They are beneficial to the consumers who purchase them and they also yield benefits to those who are producing them and to the wider community in which they are produced. Profits are made, jobs are created. Wealth is generated.

However, the ecosystem modifications required to generate these benefits have also resulted in costs. The benefits provided to the community by natural environments have been diminished because the supply of natural environments has been diminished. The loss of these benefits is a cost (known in economics as an opportunity cost) to the community.

The foregone benefits include “direct” benefits such as those enjoyed by people who visit natural environments for recreation. They can also be “indirect”. For instance, a natural environment may act as a catchment area to provide a community with high quality water. Other benefits are called “non-use” because people can enjoy them without any direct contact with the environment. Ecosystems may be valued because they enable the survival of species of plants and animals. The “existence value” so generated is enjoyed because people like to know that the species survive.

From a community wide perspective, the creation of both benefits and costs by agriculture creates a quandary. Should agricultural expansion be permitted? Should it be prevented? Or is there some intermediate position where a trade-off between the benefits and costs of agriculture is reached? Given that the benefits of agricultural expansion are likely to be greater than the costs for some expansions and less than in others, the trade-off option is clearly the preferred approach.

However, that leaves policy makers with many difficult questions to answer. For instance, how much water should be allocated to irrigated agriculture and how much should be used to maintain the integrity of downstream riverine and wetland environments? How much remnant native vegetation should be retained when properties are being cleared for grazing?

The trade-offs are also apparent in circumstances where contractions in agricultural activities are being considered. If areas of land are being taken out of agricultural production, or if less intensive use is being considered, environmental benefits may be generated. However, with less agricultural production, fewer agricultural benefits may be available. Thus, environmental benefits will be achieved but only at a cost in terms of lost agricultural production. Questions then arise such as, which lengths of the river should be fenced off to allow for habitat restoration and what area of trees should be planted to address the effects of dryland salinity?

Such questions are made more difficult because information that would be useful in developing answers is usually inadequate. The inadequacy occurs at two levels:

- Physical science. The relationships between agricultural "causes" and environmental "effects" are often poorly defined. For example, the impact on an endangered species of a tree clearing operation or the effect of fencing out a river corridor on water quality down stream may be difficult for scientists to predict.
- Social science. The values placed on the environmental "effects" by members of the community are only poorly understood and their magnitudes only rarely estimated. For instance, the values placed on recreation activities in natural environments, clean water from bush catchments or the existence of endangered species are difficult to estimate in units that are comparable to other values in the community. The unit of value most frequently used in Australian society is the dollar. Because environmental benefits not generally bought and sold in markets, valuation in dollar terms involves an extra degree of difficulty.

From the perspective of sound decision making, advances in both of these areas of information inadequacy are welcome. Better biology and ecology will yield better information on cause-effect relationships. Decision-makers will be better able to predict the consequences of alternative courses of action. Better economics will yield better information on the nature and extent of the trade-offs between agricultural benefits and environmental costs. Decision-makers will be better able to determine the alternatives that provide the greatest net-benefits to the community.

From the perspective of economics, accurate and reliable estimates of both the agricultural benefits and the environmental costs are desirable. The profession has a "head start" when attempting to estimate agricultural benefits. Most of these are bought and sold in markets and so data from those transactions are available as a base for the calculation of values. Buyers' actions in markets are a reflection of the value they place on agricultural products. Similarly, sellers' willingness to bring products onto markets provide an insight into the benefits they enjoy from production.

Without markets for environmental goods and services, it is more difficult to determine the benefits/costs they generate for members of the community. "Non-market" techniques must be employed. These techniques are of two types:

- Revealed preference techniques. These use data on peoples' preferences that are revealed in markets that are specifically related to the environmental benefit under consideration. For instance, the amount of money spent on getting to a recreation site can be used to infer the value of the experience.

- Stated preference techniques. The strength of peoples' preferences for environmental goods and services may also be gleaned from their answers to specifically designed questions. For instance, the benefit enjoyed from the continued existence of an endangered species may be estimated by asking a sample of the population for their willingness to pay a tax surcharge to fund a species protection programme.

The aim of this paper is to introduce one stated preference technique for estimating environmental values - Choice Modelling – and to provide some examples of the results its application can produce. In the next section, a brief description of Choice Modelling (CM) is provided. Two case studies in which the technique has been applied are described in Section 3. The results of these two applications are then summarised, with special attention being given to the range of forms the results can take. Finally, in Section 5, some conclusions are drawn as to the likely place of CM in the development of agricultural policy. This involves a categorisation of the relative strengths and weaknesses of the technique.

2. Choice Modelling

Choice Modelling has been developed in the marketing literature as a tool for estimating potential sales resulting from the introduction of new products or the modification of existing products. It has also been used extensively in the transport economics literature to project market shares for new modes of transport and to estimate the value of travel time. Its application in the consideration of environmental matters is relatively recent.

In the environmental context, its application relies on a sample of people who will experience the projected environmental effects under consideration answering a questionnaire in which they make choices between alternative potential scenarios. These alternatives are set out using combinations of descriptors, known as attributes. Most of the attributes are centred on the environmental effects and are described in non-monetary terms. One of the attributes involves a cost to households and is described in dollar terms. The choices faced by respondents involve different alternatives, with each being characterised by different "levels" of the attributes.

In Figure 1, a typical choice faced by a CM respondent is displayed. The example is set up to depict a case in which the environmental effects of alternative water use regimes – say in the situation where it has been proposed that water be allocated to environmental flows and away from crop irrigation - were being valued.

Respondents in a CM questionnaire would be asked to answer a number of this type of "choice set". Each choice set is different. The differences are created by systematic changes in the levels of the attributes. Only the "status quo" alternative remains constant.

Figure 1: An example of a choice set

Question: Which of the three alternatives do you prefer?

	Alternative 1: The status quo	**Alternative 2: Water diverted**	**Alternative 3: Water diverted**
Attribute 1: Number of fish species	**4 species**	**6 species**	**5 species**
Attribute 2: Frequency of bird breeding events	**every 6 years**	**every 2 years**	**Every 5 years**
Attribute 3: Stream bank vegetation	**Poor**	**Excellent**	**Good**
Attribute 4: Rates surcharge $ per annum	**$0**	**$20**	**$10**

By making their choices, respondents demonstrate their willingness to make trade-offs between the various attributes. By modelling the trade-offs made, it is possible to infer the values that respondents hold for the non-market attributes, relative to the attribute described in money terms. In other words, people's willingness to give up money (ie to pay) to secure more of the non-marketed environmental attributes can be calculated. The relative importance of the various environmental attributes can therefore be established[1].

Furthermore, the output from a CM application can be used to generate estimates of how much respondents would be willing to pay for various combinations of the attributes that describe alternative future scenarios. For instance, consider a proposal to divert water from a river for irrigated agriculture. First it would be necessary to identify and quantify any changes in the environment that would be caused. The environmental changes projected would need to be identified in terms of changes to the levels of the attributes used in the CM application to describe the alternative future scenarios. What is established through this process is a data set containing environmental attribute levels for two scenarios: the status quo and the proposed development. These data can be substituted into the choice model and an estimate of the average willingness to pay to avoid the environmental damage associated with the water diversion calculated. This is a measure of the environmental costs that will arise from the proposal.

3. The case studies

Choice Modelling has recently been trialed in two Australian agricultural case studies. The first involved the allocation of water between irrigation and wetlands in the Macquarie and Gwydir River Valleys in New South Wales. The second case study concerned the issue of tree clearing for cattle grazing in the Desert Uplands Region of Central Queensland.

[1] This type of information is useful in the development of management plans. Strategies that minimise damage to the most valuable attributes can be developed.

In both the Macquarie and Gwydir River Valleys, large scale irrigation development has taken place over the past three decades. With the diversion of water to irrigated crops and pastures, downstream wetlands have experienced declines in both area and quality. Discussions in NSW regarding the reform of the allocation of water have had the fate of wetland environments as a focus and some moves to re-allocate water resources away from irrigation and back to wetlands as "environmental flows" have already been made. Such decisions are difficult to make because they involve trade-offs between the wealth lost to the community due to potential contractions in the irrigation industries and the benefits generated by bigger and better wetlands. The CM application in this case study, was aimed at estimating the values associated with improved environments in the Macquarie Marshes and the Gwydir Wetlands. The values so estimated were intended to provide information to those involved in deciding the environmental flows for the Macquarie and Gwydir Rivers.

In the Desert Uplands, cattle graziers seeking higher returns have undertaken tree clearing. As the area of uncleared land has diminished, more and more concern has been expressed regarding the environmental consequences of continued tree clearing. The habitat modification that occurs with large-scale tree clearing is feared to threaten the survival of rare and endangered species. The Queensland Government has instituted guidelines for tree clearing in the region but these remain controversial. The CM application performed for the Desert Uplands case was aimed at providing information regarding the environmental costs of tree clearing to those involved in the process of determining the regulations for future pastoral developments in the region.

4. The results

4.1 Wetlands[2]

Three surveys were carried out to implement the CM technique in the wetlands case study:

- Macquarie Marshes –Sydney sample
- Gwydir Wetlands – Sydney sample
- Gwydir Wetlands – Moree sample.

The choice set attributes used in all the surveys were:

- Wetland area
- The frequency of waterbird breeding events
- The number of endangered and protected species present
- One-off increase in water rates
- Irrigation related employment.

The first three attributes relate to the non-market environmental features of the wetlands. The water rates attribute is the monetary attribute used to establish, in dollar terms, the trade-offs respondents are willing to make. The employment attribute was

[2] The results reported in this section are drawn from Morrison, Bennett, Blamey and Louviere (1998).

introduced in an attempt to estimate the value that people hold for other peoples' job prospects and the general economic health of a region.

The levels of these attributes were set according to the ranges that were relevant to the particular case. Hence, different levels were used for the Macquarie Marshes sample to those used for the Gwydir Wetlands samples.

The first type of result that is yielded by a CM application involves the trade-offs made between individual attributes and the monetary attribute. In other words, the application is able to provide estimates of how much on average, respondents are willing to pay to increase a non-monetary attribute by one unit. For instance, it is possible to estimate how much people are willing to pay to have an additional endangered or protected species in the wetlands. Or what an additional irrigation job is worth. These values are known as "implicit prices". The implicit prices for the wetlands case study attributes are set out in Table 1.

Table 1: Implicit prices for wetland attributes

	Area (sq kms)	Breeding frequency	Species numbers	Jobs
Macquarie Marshes: Sydney	3.4 cents (1.1 – 5.7)	\$24.15 (15.83 – 33.72)	\$4.27 (2.69 – 5.98)	10.7 cents (-2.7 –23.8)
Gwydir Wetlands: Sydney	3.9 cents (0.9 – 8.4)	\$9.81 (2.4 – 17.42)	\$3.21 (1.5 – 4.71)	21.8 cents (5.1 – 40.1)
Gwydir Wetlands: Moree	-4.7 cents (-12.6 – 3.5)	\$15.18 (2.0 – 29.95)	\$3.86 (1.15 – 6.73)	-7.7 cents (-42.9 – 21.7)

Note: 95% confidence intervals reported in brackets[3].

Hence, Sydney respondents are estimated to be willing to pay around \$24 for an increase in the frequency of bird breeding events by one year. Some attributes are not significantly different from zero. For instance, Moree respondents indicated through their choices that they were not willing to pay anything for more irrigated related jobs or for additional hectares of wetlands.

It is important to recognise that the implicit price estimates reflect trade-offs between two attributes only. Where change involves more than two attributes, implicit prices are not relevant. Then, the appropriate willingness to pay measure involves multiple attribute changes and these too can be estimated using CM results.

As an example, consider the following situation that would arise if a specific increase in the environmental flows in the Macquarie River were implemented:

- an increase in the area of the Macquarie Marshes of 500 square kilometres;
- the frequency of bird breeding to improve by one year;

[3] Tests of differences across the samples between these estimates are reported in Morrison et al (1998).

- an increase of 13 in the number of rare and endangered species present in the wetlands; and,
- the number of irrigation related jobs in the valley fell by 20

The average willingness to pay to achieve this situation of Sydney respondents was estimated to be $76.03 with a 95 per cent confidence interval of $59.07 to $92.77.

Different environmental flow policies will deliver different outcomes for the wetlands. The single application of the CM technique can be used to estimate willingness to pay for a wide range of these outcomes. So long as the attribute values that result from a proposed policy do not fall outside the range of attribute values used to estimate the CM results, the willingness to pay for the proposal can be estimated.

In the wetlands case study, values for environmental improvements were estimated. In the policy context, these values would need to be compared against the agricultural surpluses that would be lost if the augmented environmental flows were introduced. What the CM application is able to do is to produce value estimates that are compatible with that comparative process.

4.2 Remnant vegetation[4]

The tree clearing case study involved a sample of Brisbane residents. The attributes used to describe alternative tree clearing retention policy outcomes were:

- The number of endangered species lost to the region;
- Reductions in population size of non-threatened species;
- An income tax levy;
- Jobs lost in the region; and,
- Income lost to the region.

The last two attributes were included in order to estimate the values held by people living outside the region for the economic well-being of people living in the Desert Uplands.

The implicit prices estimated for the attributes were:

Endangered Species:	$17.32
Non-threatened species;	$ 2.51
Jobs:	$ 3.81
Regional income:	$ 8.80

In Table 2, some estimates of values generated by overall changes resulting from potential alternative tree retention policies are provided.

[4] The results reported in this section are drawn from Blamey, Bennett, Louviere, Morrison and Rolfe (1999).

Table 2: Willingness to pay estimates for policy alternatives.

	Endangered species	Non-threatened species	Jobs lost	Regional income lost	Value estimate
Current tree clearing guidelines	18	80	0	0	Na
Additional 10% tree retention	16	50	10	5	$83
Additional 30% tree retention	10	35	30	12	$84

The results indicate that the two policy alternatives considered generate approximately the same value for the Brisbane respondents. Tightening the guidelines by 30 per cent provides little extra gain over the 10 per cent option because the benefits enjoyed from increases in the populations of non-threatened species and the number of threatened species are matched by the costs of job losses and regional income decline. If tightening the guidelines by 30 per cent can be shown to cause grazing surpluses to be foregone, then there would appear to be no justification for that option. However, it would need to be established if the grazing surpluses foregone due to a 10 per cent increase are more or less than the environmental and social benefits estimated in the CM application before that option could be accepted or rejected.

5. Strengths and weaknesses

The applications of CM reported in this paper demonstrate the capacity of the technique to provide policy relevant information on the values people hold for non-marketed environmental and social impacts. This information is important for a number of reasons. First, with more complete information regarding the values of all the impacts, policy makers are better equipped to make decisions that are in the best interests of the whole community. Second, with improved information that is widely accessible to the public, the prospects of vested interest groups being able to "capture" the decision making process to their own advantage – and potentially to the disadvantage of the community as a whole – are diminished.

These are reasons for the estimation of non-market values. There are other reasons why CM can be regarded as superior to other techniques that have been designed and used to perform the same role.

A single application of the CM technique can produce estimates of value for many alternative policy outcomes. In addition, the composition of those value estimates can be examined through the analysis of the "part-worths" of the component attributes. This is in contrast to the most commonly used alternative non-market valuation technique, the contingent valuation method (CVM). Because CVM is based on a sample of affected people's responses to questions regarding their preferences for one alternative, it is capable of providing estimates of the value of that one alternative. That value estimate is therefore specific to a particular set of circumstances and cannot be "disaggregated" into the contributions made by the individual attributes that combine to constitute the alternative. The ability of CM to provide estimates of multiple scenarios makes it a more versatile and cost-effective technique.

An advantage of the "disaggregation" capability inherent to CM is that estimates of value derived from an application of CM at one site are more likely to be valid when "transferred" to another related site. This is because the different circumstances at the transfer site can be taken into account by adjusting the levels of the attributes accordingly. Again, because CVM results are circumstance specific, they do not offer this flexibility.

The applications of CM reported in this paper included social as well as environmental attributes as descriptors of the alternatives offered in the choice sets. These inclusions enabled the estimation of values associated with employment opportunities and regional income held by people not likely to benefit directly from the jobs or the income. These values can be likened to the "non-use" existence values held by people for endangered species: people are willing to pay to see other people employed and prosperous just as they are willing to pay to see endangered species protected. CM is capable of providing information that can be used to estimate these social values that are also non-marketed.

There are also reasons why CM yields results that are less susceptible to "strategic behaviour" on the part of respondents. A continuing concern in regard to the use of stated preference techniques is that respondents deliberately misrepresent their preferences in order to bias the study's results in their favour. Specifically, if asked in a CVM application for the amount they are willing to pay to see an environmental good enhanced, a respondent who enjoys the environmental good may overstate their true willingness to pay in order to increase the chance of the good being provided. An advantage of CM in this respect is that it is much more difficult for respondents to identify a choice strategy that will influence the results in their favour. In the face of such uncertainty, it has been shown by Bohm (1972) that respondents are more likely to tell the truth. Some evidence of the veracity of CM responses has been reported by Blamey, Bennett, Morrison and Louviere (1998) who compare CM results with market generated data for a product with some environmental attributes – toilet paper.

Whilst CM demonstrates certain advantages, it is not without challenges. Foremost of these is the problem of respondent cognition. The choice sets that form the core of CM require respondents to select their most preferred option from an array of alternatives. Each alternative is described using a number of attributes. The amount of information a respondent must assimilate and act upon is significant and in environmental CM, the situation faced by respondents is unfamiliar. This places a significant cognitive burden on the respondent. If this is not carefully managed through questionnaire design and presentation the outcome can be biased sampling or results that are driven not be careful consideration of the choice but by decision heuristics.

The application of CM is also more complex than other stated preference techniques such as CVM. The complexity extends from the questionnaire design phase right through to the data analysis stage. The added complexity, at least during the time when the technique is being established will add to the costs of application. However, as the technique's application is refined and problems resolved, these cost disadvantages will be diminished.

What this somewhat cursory treatment[5] of the strengths and weaknesses of the CM technique demonstrate is that it affords substantial promise as a means of generating policy relevant information for decision makers dealing with issues involving environmental impacts. Agriculture, because of its natural resource base, provides frequent examples of such issues.

This promise is being increasingly recognised. Currently the National Land and Water Resources Audit is commissioning a CM application to provide data on land degredation issues around Australia. At the same time, the body advising the NSW Government on water reform issues in that State – the Independent Advisory Committee on Socio-Economic Analysis (IACSEA) – is commissioning a CM application to investigate the value of environmental attributes of NSW river catchments. The growth in knowledge that these applications will provide – both in terms of the environmental values they estimate and the experience in the use of CM – will be important contributions to the development of agricultural policy.

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[5] A more complete assessment can be found in Bennett, Blamey, Morrison and Rolfe (1998).