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A choice experiment of reducing the chance of marine pest incursions in Australian waters in the presence of outcome-related risk

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Abstract

New policies often involve elements of risk regarding whether or not key policy objectives will be met after implementation. This is particularly the case for policies that aim to achieve positive environmental outcomes. The complexity of ecological systems make the scale of environmental impacts difficult to predict, and the success of policy is therefore subject to some risk. Despite this presence of risk, stated preference studies of environmental policy initiatives, including those using choice modelling, frequently assume deterministic outcomes from policy implementation. This paper presents empirical results of a choice modelling application conducted to estimate the economic value the Australian public places on reducing the chance of new marine pest incursions into Australia. The study reports the expected values (incorporating both the bio-physical outcomes and the probabilities of their achievement) of environmental attributes of new marine pest incursions into Australia. This choice modelling application required the use of a novel approach that involves the incorporation of the risk of achieving policy outcomes directly into the choice sets offered to respondents. In this way the community profile for risk aversion is taken into account when estimating willingness to pay for the policy outcomes. The incorporation of risk can enhance scenario credibility and the accuracy of willingness to pay estimates obtained using choice modelling. The study revealed that the Australian public values policies that protect the Australian environment from the potential impacts of new marine pests, especially policies that have a high chance of successfully reducing new marine pest incursions into Australia.

1 Introduction

This study uses the choice modelling (CM) approach to estimate the Australian community's willingness to pay to reduce the chance of marine pest incursions in Australian waters in the presence of outcome-related risk. The reduction in marine pest incursions is assumed to stem from new policy programs that are not yet in place. Policy programs to address marine pest risks are challenging to design and their impacts are often difficult to predict with certainty. Decision makers need to take into account a number of factors within a cost-benefit framework, such as the risk that the new policy will not meet key objectives, the community's preferences around marine pests and the relative costs and benefits of any new policy. While the costs associated with these programs are relatively straightforward to identify, there is limited information available about the potential benefits. This is partly because many of the benefits are non-market in nature.

In most stated preferences (SP) non-market valuation studies, outcomes of different policy actions are predicted under the assumption that there is certainty of these outcomes occurring (Wielgus et al. 2009, Williams and Rolfe 2017). In reality, especially where environmental outcomes are considered, there is almost always some degree of risk about the predicted outcomes. Ignoring the effect of respondents' risk preferences (risk-aversion or risk-taking) on expected utility may result in incorrect estimates of respondents' willingness to pay (WTP) for the changes in environmental outcomes (Glenk and Colombo 2013). Wielgus et al. (2009) argue that omitting risk in SP methods may contribute to hypothetical bias and compromise validity of the valuation. The relevance of inclusion of risk in stated preference (SP) studies and its impact on WTP and scenario credibility has been recently discussed in the SP literature (e.g. Akter et al. 2012, Glenk and Colombo 2010, Glenk and Colombo 2013, Newbold and Daigneauld 2009, Roberts et al. 2008, Rolfe and Windle 2015, Wielgus et al. 2009, Williams and Rolfe 2017).

The CM study reported here was designed to value the Australian communities' preference for reducing the incidence of new marine pests negatively affecting the Australian environment. With a limited knowledge available on the likelihood of new marine pest incursions, and the scale of the potential environmental impacts, credible scenarios were difficult to design assuming certainty of policy outcomes. The probability of establishment and intensity of the potential impacts of marine pests depends on many factors such as: climate, availability of food sources, resilience, and the dynamics of the environment, all of which are difficult to predict with certainty. To capture the risk of the effectiveness of the policy intervention an additional attribute: "chance", that is, that the environmental outcomes will occur as a result of a new policy, was incorporated in the design of a choice set. The inclusion of the "chance" attribute which accounts for the outcome related risk mirrors similar approaches taken in Akter et al. (2012), Glenk and Colombo (2013), Rolfe and Windle (2015) and Williams and Rolfe (2017). Previous studies investigated the impact of inclusion of risk factor as a separate attribute in a choice experiment. This study takes this further and under the assumption that preferences for different environmental outcomes depend in part on probability of achieving these outcomes, the "chance" attribute was interacted with the environmental attributes.

Instead of using utility as the subject of the respondent's maximisation problem this study uses Expected Utility (EU) as a means of incorporating the risk associated with effectiveness of the policy intervention into consumer choice. This novel approach was tested during focus groups and the pre-testing process to provide an assurance of respondents' understating of the meaning of the "chance" attribute and of the relationship between this attribute and the environmental outcome attributes. The modelling of the respondents' choices involved the chance attribute being interacted with the environmental attributes to estimate an expected value.

2 Incorporating risk in choice modelling

Risk and uncertainty in stated preference methods

A few SP studies have tested different aspects of risk and uncertainty. Glenk and Colombo (2013) tested for the impact of outcome-related risk on preferences by introducing an additional attribute in a choice model in the context of land-based climate change mitigation. The authors provided a comprehensive analysis of how respondents process information on outcome-related risk within the choice task. The study found that respondents' preferences differ significantly with the introduction of the 'additional risk of failure' attribute when choosing between alternative soil carbon sequestration programmes. The authors concluded that respondents' risk profiles such as risk aversion or risk loving should be taken into account as ignoring these factors may distort the true welfare derived from implementation of environmental projects. Another study conducted by Wielgus et al. (2009) explored the effects of including information on probabilities in choice experiments in the context of marine recreation. The study also found that additional information about probabilities of the outcomes occurring can improve the goodness of fit of choice models and the consistency of choices. The authors also argue that omitting probability information may contribute to hypothetical bias and influence the credibility of the study. Similarly, Roberts et al. (2008) showed that the inclusion of risk in the modelling of consumer preferences for environmental goods affects the values derived.

Williams and Rolfe (2017) tested the influence of including different types of risks on respondents' preferences related to reductions in national greenhouse emissions by 2020. The types of risk that were tested in the study included achieving emissions reduction and international participation as the percentage of total global emissions covered by international agreements. The results showed that respondents' choices varied with the level of risk associated with emissions reduction options.

Another CM application conducted by Rolfe and Windle (2015) elicited values for environmental improvements in the Great Barrier Reef (Australia), taking into account outcome risk. That study incorporated risk into the CM application by including a separate attribute representing the chance of the different levels of the environmental outcome being potentially achieved in the future as a result of new management actions. Results showed that respondents took into account information regarding outcome certainty. Glenk and Colombo (2010) also incorporated uncertainty and risk of failure to deliver emission savings in a CM survey on land-based climate change mitigation. The study found that the inclusion of risk impacts on the preferences for delivering emission reductions. Akter et al. (2012) tested the influence of risk as a probability of policy success in regards to climate change mitigation. The study found that mitigation policy scepticism impacted on respondents' preferences.

Theoretical model

Responses to CM questions are analysed based on the conceptual framework of a random utility model (RUM) of Thurstone (1927) and McFadden (1974). The RUM assumes that respondents have a utility for each choice alternative and part of this utility can be observed and expressed as a systematic (explainable) component, but part of the utility comprises all unidentified factors that influence choices expressed as a random (unexplainable) component. Therefore the probability, P_{an}, of the respondent n, from the choice of an alternative a can be describe as:

$$P_{an} = V_{an} + \varepsilon$$

where V_{an} is the deterministic observable component of utility and ε is the stochastic, unobserved component of utility associated with option *a* and consumer *n*. The observed component V_{an} is a function u of the attributes Z and of individual characteristics S (Rolfe et al. 2000).

$$P_{an} = u - (Z, S) + \varepsilon$$

Therefore, it is assumed that respondents choose an option from the choices that provides the highest utility of a certain outcome. This study deals with another level of risk, which is the stated chance of the predicted environmental outcomes occurring under the new policy. Predicting environmental outcomes of future impacts of new marine pests is uncertain as the impact depends on a number of variables that can affect favourable conditions for establishment and spread in a new environment. The risk associated with the outcomes occurring in a decision process is dealt with in expected utility (*EU*) theory (von Neumann and Morgenstern 1944). The von Neumann-Morgenstern utility theorem assumes that when a decision maker is faced with the risk associated with the outcomes of different choices they will behave to maximize the expected value of the outcome. *EU* is defined as the sum of the utility of outcomes weighted by their probability of occurrence *p*, allowing an observation of a respondent's attitude towards the risk affecting P_{an} (Covello, Menkes and Mumpower 1986).

$$EU = \sum p \, P_{an}$$

The *EU* is linear in the probabilities under an assumption that respondents do not have preferences over probabilities (Wand and Rolfe 2009). Parameter estimation was conducted using conditional logit (CL) model and panel error component (EC) model. The CL gives the probability of an individual *i* choosing the alternative *j* in choice situation *t* as a function of:

$$L_{ijt} = \frac{\exp(\mu \beta_{ijt})}{\sum_{q=1}^{J} (\mu \beta_{iqt})}$$

μ is the scale parameter which is usually normalised to one. β is a vector of parameters and X_{ijt} is a vector of explanatory variables that include the attributes of the alternatives. The EC used for this study is an extension of the CL model. The EC model relaxes the condition that the ε term is independently and identically distributed across alternatives by introducing the unobserved heterogeneity into the model as individual specific random effects that are distributed across the alternatives (Greene 2007 and McFadden 1974). Therefore, the EC model takes a form:

$$P_{an} = \frac{\exp(\alpha_j + \beta_i x_{ijt} + \sum_{m=1}^{M} d_{jm} \, \theta_m E_{im})}{\sum_{q=1}^{J} (\alpha_j + \beta_i x_{ijq} + \sum_{m=1}^{M} d_{qm} \, \theta_m E_{im})}$$

where α_j is alternative specific contact, x_{ijt} represents attributes, E_{im} are individual specific random components, m=1,…..M, E_{im} ~N*[0,1]*, θ_m θ_m is the scale factor for error component *m*, and d_{jm} is equal to 1 if E_{im} appears in the utility of alternative *j* and *0* otherwise (Greene 2007).

3 Questionnaire design and application

Study context

This study was undertaken to estimate the non-market value that the Australian community has for reducing the chance of new marine pests incursions and the negative effects that they may have on Australia's marine environment. Marine pests are non-native marine plants and animals that pose a threat to Australia's economy, environment or community. Australia has over 250 non-indigenous marine species and approximately 15 of them are recognised as invasive marine pests (that is, causing or capable of causing extensive impacts) (DAWR 2016, Kinloch, Summerson & Curran 2003). These species have been introduced into Australian waters in various ways including ballast water (water carried by ships for stability) and bio-fouling (attached to boat and ship surfaces) (Bax et al. 2003, DAWR 2016). Increasing global trade has increased international vessel movements and therefore the likelihood of new marine pests being introduced to Australia.

Evidence from overseas suggests that marine pests can have negative environmental effects (e.g. Bax et al. 2002, Gollasch 2011, Leppäkoski 1991, MESA 2017). However, predicting the potential scale of these impacts when introduced into the Australian environment is difficult due to differences in climate, environmental dynamics and context.

A number of initiatives, both domestic and international, have been undertaken in Australia to reduce the risk of marine pest incursions into Australia. Currently the Australian government is developing policies to improve the regulation surrounding biofouling of international vessels. Implementation of such regulations is intended to reduce the risk of non-indigenous marine species establishing in Australia and any subsequent impacts of marine pests on the Australian environment and communities (DAWR 2016). To improve the management of the marine biosecurity risks inherent in vessel movements, the Department of Agriculture and Water Resources is developing a regulatory approach for the management of the marine biosecurity risks posed by biofouling from international vessels. To inform the implementation of a new policy, it is important to consider all of the potential benefits and costs of the policy. This implies a need to identify the community's value for reducing the risk to the marine environment from the impacts of new marine pests, and to better understand the Australian community's preferences for marine biosecurity management.

The benefits from the prevention of new marine pest incursions identified in this study include the reduction of the probability of the impacts of new marine pests on native species, coastline and adjacent waters in terms of the reduction or loss of biodiversity, loss of amenity value of the coast or recreational use. As these benefits are non-market in nature, the CM non-market valuation technique was used to estimate the communities' value of reducing the risk of marine pest incursions in Australia's waters.

Questionnaire design

In this CM application each choice question included a number of options for managing marine pest incursions that respondents could choose from (see Figure 1). The options were described by the following attributes:

- number of species protected;
- length of coastline and adjacent waters protected;
- chance that outcomes of new policies will occur; and
- additional annual cost to a household.

The relevance of the attributes was determined through expert consultation and tested with the general public during a series of focus groups discussions. While there are examples of the environmental impacts of marine pests overseas, there are uncertainties about the extent to which these impacts are comparable in the Australian context. Many factors such as differences in climate, availability of food sources, ecosystem resilience, and changes in the natural environment influence the probability of pest establishment and intensity of the potential impacts. There is a risk associated with the effectiveness of new bio-fouling management practices. To reflect the risk associated with the outcomes, the attribute, "percentage chance that outcomes of new policies will occur", was incorporated into the choice questions. This attribute was presented to respondents as the percentage probability that the combined two outcomes (number of native species protected and kilometres of coastline and adjacent water protected) will occur under each of the options presented.

The probability of the outcomes of the new policy were expressed in three levels: 20%, 50% and 80%. In making their choices between alternative future policy options, respondents made trade-offs between the cost to them (additional annual cost to a household) against different levels of the environmental outcomes (number species protected and length of coastline and adjacent waters protected) and the probabilities of those environmental improvements being achieved (chance that outcomes of new policies will occur). The environmental attributes which represent the environmental outcomes as consequences of a new management. Therefore these environmental attributes and the chance attribute are mutually dependent and they cannot be interpreted separately. For example, while an option presented to a respondent might provide higher environmental outcomes than another, the probability of achieving those outcomes could be lower and a respondent may therefore choose the option with the lower environmental outcome because it has a higher probability of achieving those outcomes. This means that respondents' choices between alternative future management options is dependent on both the chance that the outcomes of new policy will occur and the environmental outcomes (number of species protected, length of coastline and adjacent waters protected).

Alternative policy actions were described together with potential consequences of the continuation of the current and alternative management actions. The information was supported by photographs and maps. It was explained in the questionnaire that the new policy requirements considered may include one or a combination of different actions.

The questionnaire included five choice questions and each of the choice questions contained three options, each with all the attributes but with varying levels of each attribute (Figure 1). A baseline option (Option A) representing the status quo (no new policy) was included in each choice question. The choices were made between the status quo option (no new policy) and two different proposed new management options (new policies).

A monetary attribute 'additional annual cost to a household' was used. It was explained to respondents that the cost of the new policy would be paid for by additional regulatory costs imposed on the shipping industry and boat owners (all types of boats coming from overseas ports), and that these costs would ultimately be passed on to households in the form of higher prices for imported goods and goods made in Australia using imported products.

Using the ©Ngene software programme an S-efficient design was employed to create the choice sets. The levels of each attribute across the predicted range were used in the design that produced 20 alternative options. These alternatives were blocked into four different versions, each with five choice sets. The choice sets within one version were ordered randomly. The order of the choices varied between the questionnaires. Two change options and a status quo Option A were included in each choice set.

Figure 1 Example of choice question

Option	Additional cost to YOUR household	Outcomes		Chance that outcomes of new policies will occur	CHOICE Tick ONE
		Species protected	Coastline and adjacent waters protected		
Option A (no new policies)	$0 per year	0 species protected	0 km protected	Not applicable	☐
Option B (new policies)	$20 per year	4 species protected	1,500 km protected	50% chance	☐
Option C (new policies)	$50 per year	6 species protected	1,000 km protected	80% chance	☐

4 Results

A web based CM survey was conducted in May and June 2017. The respondents were randomly selected from the general public. In total, 2616 valid responses were obtained from regions across Australia. Only people over 18 years old were asked to complete the questionnaire on behalf of the whole household. The estimated response rate was around 16 per cent. A chi-square test was used to determine whether there are any significant differences between the distribution of the sample and the Australian Bureau of Statistics population data. No significant differences were found for gender, age, income and tertiary education. The results also showed that the survey was consequential and easy to understand as indicated by over 90 per cent of the respondents.

The survey data obtained were analysed using conditional logit (CL) and error component (EC) models. Table 1 sets out the modelling results. The pseudo R2 for the EC model indicate a good model fit. The alternative-specific constant (ASC) was positive and significant. That implies respondents systematically preferred the change options over the status quo. The signs of the model parameters are in accordance with a priori expectations. All outcome parameter coefficients have positive values which mean that those scenarios resulting in higher amounts of marine pest prevention are preferred. The cost coefficient was significant and negative. The environmental parameters (species and coastline) were interacted with the attribute that represented the risk of policy failure represented by the attribute chance of the outcomes occurring. Therefore, the probability of a respondent choosing an improvement in environmental qualities was conditional on the chance of these outcomes occurring. Therefore, parameters were estimated for length of coastline and adjacent waters protected conditional on the chance of this outcome occurring and for native species protected conditional on the chance of this outcome. The values obtained from the model were extrapolated to a relevant chance of achieving certain probable outcomes under the assumption that the expected utilities are linear in the probabilities that characterise the chance of the outcome occurring.

In order to test for preference heterogeneity, a CL model including characteristics of the respondents was estimated (CL with interactions). The results show that the respondents who were aware about marine pests prior to answering the survey prefer management scenarios that provide higher levels of outcomes (Table 1). Similarly, respondents who use the marine environment for recreation and who lived or currently live in a coastal area preferred the change options.

Table 1 Results of the choice models

Explanatory variables	CL attributes only	CL with interactions	EC attributes only	EC with interactions
Cost to household	-.01038***(.00026)	-.01048***(.00026)	-.01160***(.00023)	-.01161***(.00023)
Chance*100km of coastline and adjacent waters protected	.000647***(.000036)	.000650***(.000036)	.000859***(.000038)	.000856***(.000038)
Chance* a species protected	.00265***(.00014)	.00268***(.00014)	.00378***(.00014)	.00377***(.00014)
ASC	.91548***(.05503)	.41631***(.06102)	2.57533***(.13195)	1.51236***(.14898)
ASC*aware about marine pests		.37816***(.05208)		.68915*** (.17321)
ASC*use marine environment for recreation		.56208***(.05747)		1.11669***(.18827)
ASC* lived or currently live in a coastal area		.41562***(.05222)		.76052***(.17454)
SigmaE01			-3.40396***(.10727)	3.31987***(.10349)
Pseudo R2	0.1596	0.1726	.3305	.3341
D.F.O	4	7	5	8
Log likelihood	-11297.13896	-11118.24641	-9620.22545	-9568.26714
Observations	13080	13080	13080	13080

Note: ***, **, * Significance at 1%, 5%, 10% level. The 95 per cent confidence intervals in brackets calculated using a bootstrapping procedure (Krinsky & Robb 1986).

Using the parameters from the model directly, the WTP values were estimated for 1% probability of a protection of 100 kilometres of coastline and adjacent waters protected and 1% probability of one native species protected (Table 2). These units of probability and environmental outcomes represent the outcomes generated by the model which do not reflect any probable outcome and should be extrapolated to more realistic probabilities (20% to 80%) and number of species (0 to 6) and length of the coastline (250km to 1500km) which is within the probable range.

Table 2 Average annual willingness to pay per household for one percent probability of success.

100 km of coastline and adjacent waters protected at one percent chance of the outcome occurring	\$0.074 (0.066 ~ 0.083)
One species protected at one percent chance of the outcome occurring	\$0.33 (0.29 ~ 0.36)

Note: ***, **, * Significance at 1%, 5%, 10% level. The 95 percent confidence intervals in brackets were calculated using a bootstrapping procedure (Krinsky and Robb 1986).

The calculations assume that the expected utilities are linear both in the probabilities that characterise the chance of the outcome occurring and the scale of each type of outcome. The analysis also calculate WTP for each outcome as independent and additive. The results WTPs for one percent chance of the outcome occurring were extrapolated to the probabilities used in the choice questions (20%, 50% and 80%) as shown in Table 3.

Table 3 Annual average household values for the prevention of marine pest impacts

Probability of success	250 km of coastal area and adjacent waters protected	One native species protected
20%	$3.70	$6.52
50%	$9.25	$16.29
80%	$14.80	$26.07

If it is expected that more species or area would be protected as a result of the management actions the values are extrapolated accordingly by the number of species or length of coastline protected. In making such extrapolations decision makers and scientists should consider relevant scenarios and possibilities of achieving the expected outcomes in terms of number of species and area of coastline protected through active management of marine pest risks and the probability that management will be successful in achieving the stated outcomes.

The benefits that the Australian community holds for prevention and avoided environmental damage from the impact of new marine pests can be directly compared to the costs of prevention at a given probability of success. Active prevention would be justified where the benefits outweigh the costs. The values obtained from this study represent the value of the environmental benefits estimated under the risk of the outcomes occurring. The estimated WTP values reflect household willingness to pay for improvements in environmental qualities and probability of these outcomes occurring.

5 Discussion and conclusion

Preferences for reducing the risk of marine pests entering and establishing in Australia was analysed using CM. The risk associated with the effectiveness of the policy and therefore the probability of the outcomes occurring was incorporated into the study using an attribute representing the chance of potential policy outcomes occurring. In the policy context, including risk in the decision process is important as it improves the credibility of the study and can provide more realistic estimates of willingness to pay estimates and therefore better policy guidance.

Due to the complexity of ecological systems, the policy outcomes of actions that affect the environment are difficult to predict with certainty. Despite the presence of risk, SP studies of environmental policy initiatives have often assumed deterministic outcomes from policy implementation. Most commonly CM applications have framed choice scenarios assuming certainty of the policy outcomes. That approach fails to account for policy failure.

This study used a novel approach that involved the incorporation of the risk of achieving policy outcomes directly into the choice sets offered to respondents. In this way the community profile for risk aversion was taken into account when estimating WTP for the policy outcomes. This study expanded the common welfare theory by incorporating preference uncertainty using the expected utility model when respondents made choices by trading off the money against the risk of the policy failure. In accordance with expected-utility theory the values obtained from studies that do not include the risk factor tend to overestimate the WTP (Wielgus 2009). In particular, this study interacted the risk attribute with the attributes representing environmental outcomes of different policy actions.

The study found that the Australian public values policies that reduce the risk of environmental damage from new marine pests, especially policies that have a high chance of successfully reducing new marine pest incursions into Australia.

The estimated expected values (incorporating both the bio-physical outcomes and the probabilities of their achievement) of reducing the impact of marine pest incursions into Australia were found to be dependent on the probability of achieving these outcomes. Policy assessment should therefore take account of the likelihood of the environmental outcomes, as well as the scale and nature of achieving desired outcomes and the cost of policy action.

The findings of this study confirm the importance of accounting for risk and uncertainty when designing policies. The results demonstrate that respondents place value on avoiding environmental damage and place higher value on options involving higher certainty that the particular outcomes will occur. The results of this study add to the emerging literature dealing with risk issues in SP methods.

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