Estimating the supply of on-farm biodiversity conservation services by north Australian pastoralists: design of a choice experiment

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Improving biodiversity conservation in northern Australia

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Abstract

This paper reports on the experimental design process and considerations of a discrete-continuous choice experiment conducted in collaboration with landholders in northern Australia. The purpose of the research is to inform the design of effective and efficient payments-for-ecosystem services schemes to safeguard north Australia's biodiversity values by promoting the contractual provision of biodiversity conservation services by landholders, in particular pastoralists and graziers.

The paper focusses in particular on the discrete choice experimental (DCE) aspects. The DCE is employed to estimate landholders' preference heterogeneity for supplying ecosystem services, specifically their willingness to accept remuneration for the on-farm conservation of biodiversity, based on potential program attributes. The design of the choice experiment draws on best practice standards (Hoyos 2010), a recognition of the benefits of embedding design in a consultative process (Klojgaard *et al.* 2012) and recent advances in accounting for response certainty (Brouwer *et al.* 2010; Hensher *et al.* 2012).

DCE design decisions relating to attribute selection, attribute levels, alternatives and choice tasks are explained based on literature, focus group discussions, expert interviews and an iterative process of efficient DCE design. Additional design aspects include (i) a set of supplementary questions after each choice set to measure respondents' choice certainty and elicit decision heuristics; (ii) embedding of the experiment in a socio-economic-psychological questionnaire, and (iii) logistical design.

Keywords

Choice experimental design, efficient design, iterative process, response certainty, willingness to accept, farmers, on-farm biodiversity conservation

Introduction

The tropical savannas of Australia cover around 1.9 million square kilometers (25% of the continent) across the north of the continent. Savanna landscapes support an abundance of endemic plants and animals, which are adapted to the harsh climatic conditions (Woinarski *et al.* 2007). Although savanna landscapes may appear relatively intact, their ecological condition has widely declined since European settlement (Lewis 2002). Land use practices, in particular over-grazing, and spread of exotic plant and animal species have caused widespread environmental degradation (Woinarski, Mackey et al. 2007).

Tropical savannas endure a combination of relative under-representation in the formal conservation estate and low participation of farmers in on-farm conservation. The states who share the tropical savannas, Queensland, the NT and Western Australia, have below-average proportions of land set aside for biodiversity conservation and protection purposes ('formal conservation estate') with 1.6, 1.7 and 1.1 per cent, respectively (compared to the national average of 1.9%, ABS 2011). Conservation reserves in northern Australia are also not large enough, on their own, to maintain viable populations of many endangered species and the ecological processes necessary to them in the long term (Bennett 1995). On-farm biodiversity conservation is therefore an important element of a strategy for safeguarding north Australia's natural heritage. A majority of farmers in the three states/territories report having native vegetation on their holdings and report protecting at least some of it (ABS 2011; ABS 2011). However, in the natural resource management regions which cover the tropical savannas, no more than 41% of farmers protect native vegetation (ABS 2011).

"The contributions of all property holders and managers are needed to maintain the North's natural values" (Woinarski, Mackey et al. 2007, p. 88). The primary land use of Australia's tropical savannas is extensive beef production. Individual beef grazing enterprises are up to 24 000 km^2 in size and carry up to 65 000 head of cattle (Bortolussi *et al.* 2005). Nowhere is on-farm conservation action more critical than on farms that cover vast tracks of land with high ecosystem values as one landholder's land use decisions can have implications for soil, water and biodiversity conditions at the regional scale.

There have been a succession of biodiversity conservation programs in Australia over recent decades, but most have been shown to be ineffective in targeting and inefficient in design (Hajkowicz 2009).

Designing incentive programs that are effective and efficient requires that policy makers have a detailed understanding of (i) the financial resources required to incentivize a sufficient number of farmers to participate in on-farm conservation and (ii) the way in which program and contract design and administrative features influence participation. This research generates such understanding by exploring how program attributes relate to landholders' willingness to participate in contractual on-farm biodiversity conservation, and how much land and what type of land they would subscribe under what conditions.

This paper describes the design process of a choice experiment as the principal method for generating data which can answer the research questions. Initial design considerations are presented, results of the DCE pretest and pilot test (completed in late 2012) shown and the updated design discussed. The DCE is embedded in a larger socio-economic survey of landholders so that choice decisions may be linked to social, psychological and economic models of decision making. Full data collection is planned for the first half of 2013.

Methodological approach

Choice experiment and WTA

Exploring agents' behavior in novel markets, in this case the question about participation in on-farm biodiversity conservation for money, poses a range of methodological challenges (Rolfe *et al.* 2004) and due to the absence of market observations a stated preference approach is required, such as a choice experiment (CE). CEs have become the method of choice to generate understanding which can support the design new agricultural markets (e.g. Lusk and Hudson 2004; Windle and Rolfe 2005; Rolfe *et al.* 2008).

This application of CE explores the potential supply of an environmental service. Respondents have exclusive property rights over their land and are being asked to voluntarily give up elements of that property right in return for remuneration, making willingness-to-accept (WTA) the correct conceptual construct to use (Carson *et al.* 2001). While WTA applications have been shown have been shown to be prone to strategic bias when compared to willingness to pay applications (e.g. Mitchell and Carson 1989; Horowitz and McConnell 2002; Grutters *et al.* 2008), CE is arguably less prone to such bias than other stated choice methods (Burton 2010). Respondents can be expected to have a high degree of task familiarity, which is important for reducing bias in stated preference studies (Schläpfer and Fischhoff 2012), as landholders are familiar with the concept of receiving payments for the provision of environmental services through a series of government programs in recent decades, including grants, auctions and cost-sharing programs.

CE elicits WTA indirectly, by asking respondents to choose between cleverly designed alternatives. CE assumes that peoples' preferences are revealed through the choices they make. The method integrates concepts of conjoint analysis and discrete choice theory (Louviere and Hensher 1982; Louviere and Woodworth 1983). Respondents of choice experiments are presented with repeated samples of hypothetical scenarios (choice sets) drawn from all possible choice sets according to statistical design principles (Ryan *et al.* 2008).

Discrete-continuous approach

This CE conceives the total supply of on-farm biodiversity conservation as a discrete-continuous problem with two separate by interdependent components (Hanemann 1984). The first component is a discrete choice experiment (DCE) to determine the weights that farmers attribute to various attributes of conservation contracts. The second component of the CE asks respondents to indicate how much land they would supply if the chosen alternative was realized. Answers to both questions are needed to determine the aggregate supply function of on-farm biodiversity conservation services.

DCEs operate at the disaggregate level, i.e. the decision maker level, where choice behaviour can be defined in terms of commodity/service qualities or attributes (Truong and Hensher 2012). They are not suited for describing aggregate consumer demand and producer supply where the quantity decision is separate from the product choice. In such situations, however, the results of DCEs can serve as building blocks of aggregate demand estimation models.

Discrete-continuous approaches have been applied variously to study consumer behaviour e.g. to model the demand by households for different types of energy (Buckley *et al.* 2012; Garrod *et al.* 2012) and water (Mitchell and Carson 1989; Olmstead *et al.* 2007). The aggregate (second) component can use different types of methods, e.g. simulation models or computable general equilibrium models.

There are several recent examples in environmental literature which utilise discrete continuous choice. A study by Lohr and Park (2011) investigated the discrete choice to participate in a filter strip program and the continuous choice of how many acres to plant. They found that willingness to accept payments and acres planted was not uniform across locations. Lynch, Hardie and Parker (2012) studied landowners willingness to plant or increase the size of streamside buffers and the total area they would plant. Significant variables investigated included land already planted with buffers, knowledge of buffers and previous participation in government programs. Lambert, Sullivan and Claasen (2007) examined landowners willingness to enrol in a conservation reserve program using discrete continuous choice. The discrete component compared program components such as land retirement or working land projects and participation in conservation reserve programs and the continuous component involved land enrolled. Participation was dependent upon factors such as farm structure, personal attributes, farming experience and environmental factors.

Design of the discrete choice experiment

The aim of a DCE is to estimate the weights that respondents place on each of the attributes which define the alternatives. A respondent acting rationally is expected to evaluate the alternatives in a choice set and choose that alternative which gives the greatest relative utility (Hensher *et al.* 2005).

Thus, a respondent will choose alternative A over B, if $U(X_A, Z) > U(X_B, Z)$, where U represents the respondent's indirect utility function from certain alternatives, X_A the attributes of alternative A, X_B the attributes of alternative B, and Z the socio-economic, attitudinal and other characteristics that influence the respondent's utility. Choices made in DCEs are analyzed using random utility theory, meaning a stochastic error term ε is included in the utility function to reflect the unobservable factors in the respondent's utility function (Hensher, Rose et al. 2005). Thus, a respondent will choose alternative A over B, if $V(X_A, Z) + \varepsilon_A > V(X_B, Z) + \varepsilon_B$, where V is the measurable component of utility estimated empirically, and ε_A and ε_B reflect the unobservable factors in the respondent's utility function of alternative A and B respectively.

Design dimensions fundamentally influence the results of choice experiments and resulting recommendations (Rolfe and Bennett 2009). In particular, design dimensions influence the fit of the econometric model applied to data analysis, as measured by the relative size of ε. A good design is able to explain more of the observed variance and minimizes the stochastic element.

Decisions regarding experiment design that need to be made prior to construction of the experimental design matrix include (Hoyos 2010; Bliemer and Rose 2011):

- What alternatives, attributes and attribute levels should be included in the experiment?
- What response mechanism will be used (e.g. pick one or best-worst or others)?
- What will the utility function look like?
- What model will most likely be estimated after data collection?

- What statistical properties should the experimental design display (e.g. efficient or orthogonal or others)?
- How many choice tasks should the design include?
- How will the survey be administered once the design has been generated?

Answers to these questions are provided below before the final design is exemplified.

Choice alternatives and response format

Responses in a DCE can take on different formats including 'pick-one', 'best-worse', and others. This research applies a combination of the 'pick-one' and 'best-worst' formats.

The number of alternatives in a DCE used has a large influence on error variance. According to Caussade *et al*. (2005) it has the second largest influence on error variances out of all design dimensions with four alternatives being superior to three or five in terms of scale effects. More alternative increase the cognitive burden on respondents but Henscher (2006) illustrates that relevance of alternatives is more important than trying to limit cognitive burden of respondents.

A 3-alternative design is adopted. A 'none' option is also included to reflect unconditional demand and thus ensure conceptual validity of the design given the voluntary nature of farmer participation in a payments-for-ecosystem services program. Rolfe and Bennett (2009) found that a 3-alternative design (with a 'not sure' option) generated more participation compared to a 2-alternative design and was therefore preferable. However, Adamowicz et al. (2005) found that respondents in the 3-alternative version were more likely to choose a status quo option than in the 2-alternative version.

The alternatives of the DCE are of an unlabeled type (Louviere *et al.* 2000) and have generic titles (options 'A', 'B' and 'C') because this fits with the generic nature of the project's investigation of the role that attributes of biodiversity conservation contracts play in acceptance by farmers. Unlabeled designs have been shown to increase respondents' attention to attributes and are therefore more suitable to investigating trade-offs between attributes (de Bekker-Grob 2009).

Attributes and attribute levels: a consultative process

A key design task is to identify all the attributes that critically influence peoples' decision making and the levels of each attribute so that the resulting choice model can correctly estimate the weights of attributes. A list of possible attributes can be created a priori but must be refined through focus groups and pilot studies (Ryan, Gerard et al. 2008). The attributes must give a clear picture of the trade-offs between the choices and the outcomes (Ryan, Gerard et al. 2008; García-Llorente *et al.* 2012). Attribute levels need to be relevant and easy to understand. Choice experiments that include a policy question or a political challenge must be included and explained when choosing attributes (Barkmann *et al.* 2008).

There are a suite of factors influencing the decision of farmers to participate in conservation programs, including program, farm and personal characteristics (Productivity_Commission 2001). The attributes of the DCE reflect the program characteristics, while respondent characteristics are captured in the remainder of the survey.

An initial listing of potential attributes was established from the literature and included remuneration received, contract duration, initiator of contract, restrictions to pastoral land use combined with additional biodiversity-related management effort, monitoring arrangements, flexibility of contract and administration load (including: Rolfe, Alam et al. 2004; Rolfe and Windle 2005; Windle *et al.* 2005; Horne 2006; Ruto and Garrod 2009; Vedel *et al.* 2010; Peterson 2011; Peterson *et al.* 2011; Yu and Belcher 2011; Broch and Vedel 2012).

The critical role of embedding design in a qualitative process is recognized (e.g. Hoyos 2010; Klojgaard, Bech et al. 2012). Focus group discussions were conducted with graziers and pastoralists in north Queensland and the Northern Territory in September and October 2012 to glean insights into how farmers made decisions about participation in PES schemes, to establish whether the suggested attributes were valid, important and comprehensive in the given context, and to establish possible attribute levels for inclusion in the DCE.

Given the large influence of the monetary attribute on model outcomes (third largest influence on error variances out of all design dimensions; Caussade *et al.* 2005), the choice of compensation levels was further guided by historical data about the land productivity of the tropical savannas, in particular the value of cattle sales per hectare during 1992-2011 as derived from farm survey data (ABARES 2012). The resulting attributes and levels are summarized in Table 1.

An explicit objective of the DCE pretest and pilot survey, conducted during November and December 2012, was to review task complexity and cognitive burden to respondents and the possibility of omitted relevant attributes. Cognitive burden was found to be acceptable and there were no omitted variables. To the contrary, respondents were found to build their choices around four criteria rather than the six included, namely conservation requirement, remuneration, contract duration and flexibility. Source of funding and monitoring arrangements did not explicitly feature in the reasons given by respondents for choices made.

Efficient design

There are broadly two schools of thought about the statistical properties of experimental design display, efficient design versus orthogonal design. Orthogonality is defined and constructed in relation to the design codes. It assumes that attributes are independent of each other or uncorrelated. A design is orthogonal when every pair of levels occurs equally often across all pairs of attributes, or when the frequency for level pairs are proportional instead of equal. While orthogonal designs are more prevalent in the literature, efficient design has recently emerged as an alternative with new algorithms to facilitate the design. Efficient design has been empirically shown to lead to smaller standard errors in model estimation at smaller sample sizes compared to orthogonal design (Bliemer and Rose 2010; Bliemer and Rose 2011). This is a distinct advantage for the proposed choice experiment given the small sample size envisaged for this research. Also, because the number of choice sets of the efficient design has no influence on the efficiency of the design (Bliemer and Rose 2012), the number of choice sets can be limited to smaller numbers than in comparative orthogonal designs.

Efficient non-orthogonal designs require parameter priors to be available from literature, expert judgment or pilot studies. Experimental designs are only efficient under the assumption that the assumed priors are reasonably accurate. If there are no priors available (i.e. assumption $\hat{\beta}=0$), a pilot survey of approximately 10% of respondents based on orthogonal design is recommended as a strategy for developing a data foundation to estimate priors, then

Table 1: Attributes included in the DCE pretest/pilot design

Types of attributes	Attribute definition	Details; Attribute levels
Conservation service	Focus is on broad-acre species conservation (as opposed to localised hotspots) with flagship species group: birds such as brolga *(Grus rubicunda)* and sarus crane (*Grus antigone)*. Opportunity cost and additional management costs defined.	Defined relative to cattle grazing: expressed in terms of exclusion of cattle from the area subscribed to biodiversity conservation. 3 levels SHORT exclusion period each year e.g. during nesting season with zero reduction in cattle production from that land and no additional management required PROLONGED periods of cattle exclusion, e.g. wetlands during dry season; riparian areas during wet season resulting in a 50% reduction in cattle production from that land; no 'additional' management. TOTAL exclusion of cattle resulting in a100% reduction in cattle production from that land. Weed and feral animal control to be conducted and burning regime as defined necessary.
Remuneration	Annual payment received, $/ha, indexed over the contract period	5 levels: $2, $4, $8, $12, $16
Contractual conditions	Contract duration	4 levels: 5,10,20,40 years
	Flexibility	2 levels: No flexibility, meaning stringent enforcement of contract conditions and/or potential penalties Flexibility: Option to 'suspend' participation in contracts of >5 year duration in 'exceptional' circumstances—no payment received, no penalty to be paid; frequency <= 1 in 5 years.
	Monitoring	2 levels: External monitoring: The administrating agency undertakes regular monitoring or contracts an independent provider to undertake the monitoring. Self: The pastoralists provides the monitoring but random spot-checks are conducted by the administrating body to safeguard contractual compliance and ensure validity of monitoring results.
Sector providing the funding	Funding source	3 levels: Government: taxpayer funded program; Corporate sector, e.g. as part of an off-set program Philanthropic sector

establish the efficient design before rolling out the efficient design experiment for the remaining 90% of respondent.

Efficient design, in the absence of known priors, requires a sequential design process. For the pretest/pilot, choice sets were developed on the basis of priors leaned from the literature and focus group discussions with landholder. Priors β_k for parameters k were defined as Bayesian prior parameter distributions, assuming a normal distribution of parameter value with a mean value $\hat{\mu}_k$ and standard deviation $\hat{\sigma}_k$ so that $\beta_k \sim N(\hat{\mu}_k, \hat{\sigma}_k^2)$.

The pretest/pilot DCE results were analysed by random parameters logit (RPL) to capture parameter variation between respondents. The model was run in NLOGIT 5 software (Econometric_Software_Inc 2012). The results confirmed the direction of the attribute influence in all cases and the magnitude of prior in all cases except 'flexibility', and 'contract length', both of which were found to have larger parameter values than anticipated. The RPL parameter estimates served as priors for the revised efficient design adopted in the full survey. Both the pretest/pilot and revised Bayesian design parameters are shown in Table 2.

Table 2: Attribute priors employed for Bayesian efficient DCE design, for pretest/pilot and full survey

Attribute	**Pilot: Initial prior estimates from literature and focus group meetings as defined by $\hat{\mu}$ and $\hat{\sigma}$**	**Full survey: Revised $\hat{\mu}$ and $\hat{\sigma}$ obtained by RPL modelling of pretest & pilot DCE responses**
Conservation [1) 2)] requirement	$\hat{\mu}_{\text{C-LONG}} = -0.8$, $\hat{\sigma}=0.3$ $\hat{\mu}_{\text{C-TOTAL}} = -1.6$, $\hat{\sigma}=0.8$	$\hat{\mu}_{\text{C-LONG}} = -0.7^{*}$, $\hat{\sigma}=0.4$ $\hat{\mu}_{\text{C-TOTAL}} = -1.6^{*}$, $\hat{\sigma}=0.8$
Annual payment	$\hat{\mu}_{\text{Pay}} = 0.2$, $\hat{\sigma}=0.1$	$\hat{\mu}_{\text{Pay}} = 0.33^{***}$, $\hat{\sigma}=0.1$
Contract length	$\hat{\mu}_{\text{Years}} = -0.05$, $\hat{\sigma}=0.03$	$\hat{\mu}_{\text{Years}} = -0.18^{**}$, $\hat{\sigma}=0.08$
Flexibility [1)]	$\hat{\mu}_{\text{Flex}} = 0.6$, $\hat{\sigma}=0.4$	$\hat{\mu}_{\text{Flex}} = 2.4^{***}$, $\hat{\sigma}=0.9$
Monitoring [1)]	$\hat{\mu}_{\text{Mont}} = 0.4$, $\hat{\sigma}=0.3$	$\hat{\mu}_{\text{Mont}} = 0.6$, $\hat{\sigma}=0.5$

[1)] dummy variable, [2)] effects variable in revised design
*=significant at p<0.1, **=significant at p<0.05, ***=significant at p<0.01
Attribute 'Funding source' not shown as eliminated from DCE after pretest

Other changes to the design specifications were the omission of 'funding source' as an attribute and reduction of the longest contract duration level from 40 years to 30 years. These decisions were supported by respondent feedback volunteered during the survey pilot and the data analytical results. 'Monitoring' was shown to be significant at p<0.1 in the multinomial logit (MNL) model while the dummy variable 'source of funding' was not significant in the MNL and RPL models.

All choice sets were created in Ngene 1.1.1 (ChoiceMetrics 2012) using a Bayesian D-efficient design (Bliemer and Rose 2011). A multinominal logit design was used without accounting for covariate effects. A constant representing the 'none' option was included in the design. Dominant and redundant choice sets were prevented by defining design restrictions. The Modified Federov algorithm was used because it does not force attribute-level balance in the design.

The number of choice tasks answered by each respondent has been shown to impact on error variances (Hensher 2006) but the effect is small compared to other design dimensions (Caussade, Ortúzar et al. 2005). The question is what number of choice tasks is sufficient from a statistical design perspective. The guiding rule to answering the question is that the total number of independent choice probabilities should at least be equal to the number of parameters K in the utility function as each parameter requires a degree of freedom to be estimated (Bliemer and Rose 2012). Each choice task, S, contains up to $J - 1$ independent choice observations. The overall design will have $S \times (J - 1)$ independent choice observations. Given that the number of alternatives has been determined to be four $J = 4$ and $K = 13$, the smallest possible design (minimum number of choice tasks) following $S > 13 \div 3$ is five. Given that the design is to be an efficient design rather than a balanced or orthogonal design, there are no further statistical requirements regarding the minimum set of choice tasks (Bliemer and Rose 2012).

Pretest respondents answered 36 discrete choice tasks while pilot respondents, who completed the entire survey, answered 12 choice tasks. In the full survey, a set of 24 choice sets were developed and grouped into three blocks, i.e. each respondent will answer eight choice tasks.

The global level of efficiency is commonly expressed as the D-error, which minimizes the determinant of variance-covariance matrix. The smaller the D-error, the more statistically efficient is the design. The D-error for the final design is 0.0716, indicative of a good design.

Additional CE dimensions

Design

The DCE complements the ‘pick-one’ format (“Which options would you choose?”) with questions gleaned from the ‘best-worst’ format. Best-worst takes advantage of an individual’s ability to identify extreme options and it is easy for respondents to understand (Morrison *et al.* 2002; Flynn *et al.* 2007). By asking respondents their second preferred and least preferred options, additional insights into respondents’ preferences can be obtained.

Respondents are asked how certain they are about their ‘pick one’ response following Hensher *et al.* (2012). The certainty question can be used to weight the sample, and is one way to account for the perceived risk of the alternative (Blamey *et al.* 2000).

The continuous element of the choice experiment is captured by the question, how much land the respondent would seek to subscribe to a scheme of the type captured by the chosen alternative. This information supports estimation of the total conservation area conditional on the discrete choices made.

There is also a supplementary question asking what type of land this is, so as to be able to ascertain the conservation value of the land on offer. Landowners make choices between competing land uses which depend on differences in land quality (Krosnick and Fabrigar 1997). Biodiversity and production values of different land types of each farm are explored in other survey questions.

Infrastructure costs, including fencing and additional stock watering points, can constitute a large share of biodiversity conservation expenses. They are excluded from the discrete choice experiment as they are dependent on the farm-individual situation such as current infrastructure, and the specific area of land the respondent intends to subscribe. To enable an estimation of the infrastructure cost component of on-farm biodiversity conservation to the funder of a program, respondents were asked to provide estimates of new infrastructure required. One of the resulting choice situations is shown in Table 3.

Table 3: Illustration of a choice situation

	Option A	Option B	Option C	None
Conservation requirements	Total exclusion of cattle + managing for biodiversity outcomes	Cattle exclusion for short periods of time; zero loss of cattle production	Cattle exclusion for prolonged periods; 50% loss of cattle production	
Annual payment ($/ha)	$ 12 / ha	$ 4 / ha	$ 4 / ha	
Contract length (years)	20 years	10 years	5 years	
Flexibility of conditions	Flexibility	No flexibility	No flexibility	
Monitoring conducted	External	Self (25% random spot-checks)	Self (25% random spot-checks)	
Q1: Which option would you choose?	○	○	○	○
Q2: Which do you rate as the second best option?	○	○	○	○
Q3: Which is your least preferred option?	○	○	○	○
Q4: How certain are you of the choice you made in Q1? Please indicate % certainty on the scale.	0% 10 20 30 40 50 60 70 80 90 100% Level of certainty			
If you chose **A, B or C** in Q1, please continue to Q5. If you chose 'None' , please go to next page.				
Q5: How much land would you offer to subscribe to the program? (minimum 400 ha / 1000 acres)	.... Hectares .... Acres (Alternatively: .... % of property area)			
Q6: How did you determine the size of land area?				
Q7: What type of land is this?				
Q8: Indicatively, how much up-front infrastructure investment would be required to implement your proposal?	.... km fencing Number of new watering points			

Survey administration

The choice experiment is embedded in a hard copy survey of graziers, which explores aspects of the business, land management system, cattle operation, risk management, attitudes and personal and family circumstances. The survey is administered in a face-to-face situation during focus group discussions with groups of graziers. Focus group discussions are organized to value-add to other industry events such as branch meetings of industry associations or events organized by Landcare or regional natural resource management groups. Focus group discussions are scheduled to take two hours and participants are remunerated.

Concluding comments

A discrete-continuous choice experiment is proposed to provide answers to two questions: Under what conditions are north Australian pastoralists and graziers willing to participate in voluntary on-farm biodiversity conservation schemes? And, how much land are they willing to enroll under which conditions? Answers to both questions are required to estimate the potential supply curve of agricultural land for biodiversity conservation purposes. This paper describes how a sequential process with different stages of industry consultation and participation was used to derive at an efficient design for the discrete component of the choice experiment.

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References

ABARES (2012). AGSURF Data. Australian Government, Department of Agriculture, Fisheries and Forestry, ABARES, Canberra.

ABS (2011). Data Cube: Land management practices - environmental conservation by NRM region. Australian Bureau of Statistics, Canberra.

ABS (2011). Land Management and Farming in Australia 2009-10. Australian Bureau of Statistics, Canberra.

Adamowicz, V., Dupont, D. and Krupnick, A. (2005). Willingness to pay to reduce community health risks from municipal drinking water: a stated preference study, *Working Paper. Report written for the United Stated Environmental Protection Agency*. University of Alberta, Edmonton, CA.

Barkmann, J., Glenk, K., Keil, A., Leemhuis, C., Dietrich, N., Gerold, G. and Marggraf, R. (2008). Confronting unfamiliarity with ecosystem functions: The case for an ecosystem service approach to environmental valuation with stated preference methods, *Ecological Economics* 65, 48-62.

Bateman, I.J., Mace, G.M., Fezzi, C., Atkinson, G. and Turner, K. (2011). Economic analysis for ecosystem service assessments, *Environmental and Resource Economics* 48, 177-218.

Bennett, A. (1995). Wildlife conservation and management on private land—facing the challenge. in Bennett, A., Backhouse, G. and Clarke, T. (eds.), *People and Nature Conservation: Perspectives on Private Land Use and Endangered Species Recovery*. Transactions of the Royal Zoological Society of New South Wales, Sydney, pp 119-127.

Blamey, R.K., Bennett, J.W., Louviere, J.J., Morrison, M. and Rolfe, J. (2000). A test of policy labels in environmental choice modelling studies, *Ecological Economics* 32, 269-286.

Bliemer, M.C.J. and Rose, J. (2012). Choice Experiment Design. Workshop 13-17 February 2012. The University of Sydney: Institute of Transport and Logistics Studies, Sydney.

Bliemer, M.C.J. and Rose, J.M. (2010). Construction of experimental designs for mixed logit models allowing for correlation across choice observations, *Transportation Research Part B: Methodological* 44, 720-734.

Bliemer, M.C.J. and Rose, J.M. (2011). Experimental design influences on stated choice outputs: An empirical study in air travel choice, *Transportation Research Part A: Policy and Practice* 45, 63-79.

Bortolussi, G., McIvor, J., Hodgkinson, J., Coffey, S. and Holmes, C. (2005). The northern Australian beef industry, a snapshot. 1. Regional enterprise activity and structure. , *Australian Journal of Experimental Agriculture* 45, 1057-1073.

Broch, S.W. and Vedel, S.E. (2012). Using choice experiments to investigate the policy relevance of heterogeneity in farmer agri-environmental contract preferences, *Environmental and Resource Economics* 51, 561-581.

Brouwer, R., Dekker, T., Rolfe, J. and Windle, J. (2010). Choice certainty and consistency in repeated choice experiments, *Environmental and Resource Economics* 46, 93-109.

Buckley, C., Hynes, S. and Mechan, S. (2012). Supply of an ecosystem service—Farmers' willingness to adopt riparian buffer zones in agricultural catchments, *Environmental Science and Policy* 24, 101-109.

Burton, M. (2010). Inducing strategic bias and its implications for choice modelling design. Research Report No. 61. University of Western Australia, Perth.

Carson, R.T., Flores, N.E. and Meade, N.F. (2001). Contingent valuation: controversies and evidence, *Environmental and Resource Economics* 19, 173-210.

Caussade, S., Ortúzar, J.D., Rizzi, L.I. and Hensher, D.A. (2005). Assessing the influence of design dimensions on stated choice experiment estimates, *Transportation Research Part B: Methodological* 39, 621-640.

ChoiceMetrics (2012). Ngene 1.1.1, Australia.

de Bekker-Grob, E.W. (2009). Discrete choice experiemnts in health care: theory and applications, PhD, Erasmus University, Rotterdam.

Econometric Software Inc (2012). NLOGIT 5, Australia.

Flynn, T.N., Louviere, J.J., Peters, T.J. and Coast, J. (2007). Best–worst scaling: What it can do for health care research and how to do it, *Journal of health economics* 26, 171-189.

García-Llorente, M., Martín-López, B., Nunes, P., Castro, A. and Montes, C. (2012). A choice experiment study for land-use scenarios in semi-arid watershed environments, *Journal of Arid Environments* 87, 219-230.

Garrod, G., Ruto, E., Willis, K. and Powe, N. (2012). Heterogeneity of preferences for the benefits of Environmental Stewardship: A latent-class approach, *Ecological Economics* 76, 104-111.

Grutters, J.P.C., Kessels, A.G.H., Dirksen, C.D., van Helvoort-Postulart, D., Anteunis, L.J.C. and Joore, M.A. (2008). Willingness to accept versus willingness to pay in a discrete choice experiment, *Value in Health* 11, 1110-1119.

Hajkowicz, S. (2009). The evolution of Australia's natural resource management programs: towards improved targeting and evaluation of investments, *Land Use Policy* 26, 471-478.

Hanemann, W.M. (1984). Discrete/continuous models of consumer demand, *Econometrica* 52, 541-561.

Hensher, D.A. (2006). How do respondents process stated choice experiments? Attribute consideration under varying information load, *Journal of Applied Econometrics* 21, 861-878.

Hensher, D.A., Rose, J.M. and Beck, M.J. (2012). Are there specific design elements of choice experiments and types of people that influence choice response certainty?, *Journal of Choice Modelling* 5, 77-97.

Hensher, D.A., Rose, J.M. and Greene, W.H. (2005). *Applied Choice Analysis: A Primer*. Cambridge University Press, Cambridge, UK.

Horne, P. (2006). Forest owners' acceptance of incentive based policy instruments in forest biodiversity conservation-A choice experiment based approach, *Silva Fennica* 40, 169.

Horowitz, J.K. and McConnell, K.E. (2002). A review of WTA/WTP studies, *Journal of Environmental Economics and Management* 44, 426-447.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments, *Ecological Economics* 69, 1595-1603.

Johnson, F., Kanninen, B., Bingham, M. and Özdemir, S. (2007). Experimental design for stated-choice studies, *Valuing Environmental Amenities Using Stated Choice Studies*, pp 159-202.

Klojgaard, M., Bech, M. and Sogaard, R. (2012). Designing a CDE: the value of a qualitative process, *Journal of Choice Modelling* 5, 1-18.

Krosnick, J.A. and Fabrigar, L.R. (1997). Designing rating scales for effective measurement in surveys. in Lyberg, L.E., Biemer, P., Collins, M., De Leeuw, E.D., Dippo, C., Schwartz, N. and Trewin, D. (eds.), *Survey measurement and process quality*. Wiley, New York, pp 141-164.

Lewis, D. (2002). *Slower than the eye can see: Environmental change in northern Australia's cattle lands*. Tropical Savannas CRC, Darwin.

Louviere, J.J., Hensher, D. and Swait, J.D. (2000). *Stated choice methods: analysis and application*. Cambridge University Press, Cambridge.

Louviere, J.J. and Hensher, D.A. (1982). Design and analysis of simulated choice or allocation experiments in travel choice modeling, *Transportation Research Record*.

Louviere, J.J. and Woodworth, G. (1983). Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data, *Journal of marketing research*350-367.

Lusk, J.L. and Hudson, D. (2004). Willingness-to-pay estimates and their relevance to agribusiness decision making, *Applied Economic Perspectives and Policy* 26, 152-169.

Mitchell, R.C. and Carson, R.T. (1989). *Using surveys to value public goods: the contingent valuation method*. Resources for the Future, Washington D.C.

Morrison, M., Bennett, J., Blamey, R. and Louviere, J. (2002). Choice modeling and tests of benefit transfer, *American Journal of Agricultural Economics* 84, 161-170.

Olmstead, S.M., Michael Hanemann, W. and Stavins, R.N. (2007). Water demand under alternative price structures, *Journal of Environmental Economics and Management* 54, 181-198.

Peterson, J.M. (2011). Buying environmental improvements from farmers who screen on contract attributes, *AERE Inaugural Summer Conference*, Seattle, pp 17.

Peterson, J.M., Smith, C.M., Leatherman, J.C., Hendricks, N.P. and Fox, J.A. (2011). The role of contract attributes in purchasing environmental services from landowners. Kansas State University, Kansas.

Productivity_Commission (2001). Constraints on private conservation of biodiversity, *Commission Research Paper*. Productivity Commission, Canberra, pp 116.

Rolfe, J., Alam, K., Windle, J. and Whitten, S. (2004). Designing the choice modelling survey instrument for establishing riparian buffers in the Fitzroy Basin (Establishing the Potential for Offset Trading in the Lower Fitzroy River Research Report No. 3). Central Queensland University, Emerald, QLD.

Rolfe, J. and Bennett, J. (2009). The impact of offering two versus three alternatives in choice modelling experiments, *Ecological Economics* 68, 1140-1148.

Rolfe, J., McCosker, J. and Windle, J. (2008). Identifying the incentives that graziers in central-western Queensland need to manage land for conservation outcomes, *The Rangeland Journal* 30, 297-303.

Rolfe, J. and Windle, J. (2005). Establishing the potential for offset trading in the Lower Fitzroy River. Research Report No. 6. Final report for MBI project 53. Central Queensland University, Emerald, Qld.

Ruto, E. and Garrod, G. (2009). Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach, *Journal of Environmental Planning and Management* 52, 631-647.

Ryan, M., Gerard, K. and Amaya-Amaya, M. (2008). Discrete choice experiments in a nutshell. in Ryan, M., Gerard, K. and Amaya-Amaya, M. (eds.), *Using Discrete Choice Experiments to Value Health and Health Care*. Springer Amsterdam, pp 13-46.

Schläpfer, F. and Fischhoff, B. (2012). Task familiarity and contextual cues predict hypothetical bias in a meta-analysis of stated preference studies, *Ecological Economics* 81, 44-47.

Truong, T. and Hensher, D. (2012). Linking discrete choice to continuous demand within the framework of a computable general equilibrium model for the analysis of wider economic impacts of transport investment projects, *Transportation Research Part B: Methodological* 46, 1177-1201.

Vedel, S.E., Jacobsen, J.B. and Thorsen, B.J. (2010). Contracts for environmental goods and the role of monitoring for landowners' willingness to accept, *Fourth World Congress of Environmental and Resource Economists*, Montreal.

Windle, J. and Rolfe, J. (2005). Diversification choices in agriculture: a Choice Modelling case study of sugarcane growers, *Australian Journal of Agricultural and Resource Economics* 49, 63-74.

Windle, J., Rolfe, J., Whitten, S.M. and Alam, K. (2005). Establishing the potential for offset trading in the Lower Fitzroy River. Research Report No. 5. Using Choice Modelling to establish the supply of riparian services. Central Queensland University, Emerald, Qld.

Woinarski, J.C.Z., Mackey, B., Nix, H. and Traill, B. (2007). *The nature of Northern Australia: natural values, ecological processes and future prospects*. ANU E Press, Canberra.

Yu, J. and Belcher, K. (2011). An economic analysis of landowners' willingness to adopt wetland and riparian conservation management, *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 59, 207-222.