Using choice experiments to assess the costs of supplying carbon offsets in beef production systems

Rebecca Gowen

CQ UniversityAustralia

Contributed paper prepared for presentation at the 59th AARES Annual Conference, Rotorua, New Zealand, February 10-13, 2015

Using choice experiments to assess the costs of supplying carbon offsets in beef production systems

Abstract

Stated preference experiments have been used successfully to value non-market amenities such as biodiversity and aesthetics (Ballweg, 2013; Horne, 2006). These experiments have predominantly been applied to estimating how much consumers would be willing to contribute to preserving some natural feature, that is their demand for either use or non-use values of an environmental asset. The supply of carbon offsets from agricultural land has many of the same characteristics as these amenities but also represents a possible alternative (or complementary) enterprise for private agricultural landholders. The supply of carbon offsets from agricultural land in Australia has previously been estimated based on biophysical characteristics and using bioeconomic modelling but the resulting models do not necessarily reflect the underlying preferences of landholders for supplying offsets. This paper reports the use of stated preference techniques to estimate the cost of supply of a carbon offset enterprise on land currently under cattle production. Specifically the value to be estimated is landholders' willingness to accept (WTA) a payment to reduce cattle production in favour of producing carbon offsets. The results showed that both landholder and contract conditions were significant in determining preferences for producing carbon offsets as well as the influence of bounded rationality, hyperbolic discounting and inertia on preferences.

1.1 Introduction

Agricultural lands have the biological potential to sequester atmospheric carbon dioxide and thus have been identified by both scientists (Eady et al., 2009) and policy makers (Garnaut, 2011) as a major potential source of offsets to reduce the impact of the greenhouse effect. Carbon offsets represent a possible alternative (or complementary) enterprise for agricultural land. On first examination this choice appears not much different from the choice between producing different agricultural products such as goats or cattle. However, the operational changes at the producer level required to create these offsets are neither insignificant nor uniform across enterprises. Further, carbon offsets are an intangible product and there is almost no existing market information on the potential costs and returns of producing carbon offsets. There are also no related markets and no close substitutes. As such carbon offsets have many of the same characteristics as non-market values such as biodiversity and aesthetics which have successfully been measured using stated preferences.

SP experiments with regards to environmental issues are not uncommon but have been most commonly applied to estimating the amount that consumers would be willing to contribute to preserving or protecting some natural feature, that is their demand for either use or non-use values of an environmental asset. Conversely, this study applies the technique to estimate supply of an environmental asset through adoption of a carbon offset enterprise. Specifically the value to be estimated is landholders' willingness to accept (WTA) a payment to reduce cattle production in favour of producing carbon offsets with the hypothesis that longer contracts and greater monitoring and reporting requirements will have an inverse impact on the willingness of landholders to incorporate a carbon offset enterprise into their business.

1.2 Literature review

Stated preference methods can be used to construct supply and demand functions based on how people state that they would behave in a given situation (Bennett and Blamey, 2001). Stated preference techniques work by asking respondents to indicate preferences between a series of alternatives defined by a range of characteristics including a payment or cost variable. By varying the levels of the characteristics (attributes) monetary estimates can be made of the level of utility provided by each attribute. This methodology has most commonly been used to estimate a respondents' willingness to pay (WTP) to procure an additional unit of the good or their willingness to accept compensation in return for production of the good being reduced. Although WTP and WTA are theoretically equal, divergence between the two measures has been demonstrated to occur under a range of conditions (for example Kahneman et al., 1991; Knetsch, 1989; Plott and Zeiler, 2005; Shogren et al., 2001).

The application of stated preference methods to environmental issues is growing in popularity as both corporations and public institutions seek information on the value of different environmental goods and services (Rolfe and Bennett, 2006). However, there are very few studies that have used stated preferences (specifically choice modelling) to estimate preferences for producing carbon offsets. One recent study has used choice modelling (CM) to estimate community values for the benefits of carbon farming {Kragt, 2012 #52} and another even more recent study used CM to examine the factors influencing farmers participation in biodiversity contracts {Greiner, 2015 #140} .

Choice modelling (CM) developed out of contingent valuation modelling (CVM) and is similar to CVM but instead of making a single choice between two options respondents have to indicate their preferences between a series of policy or market options, each defined by varying levels of several attributes. The methodology is based on the assumption that choices are made based on a combination of the attributes of a good.

The choice model is constructed such that the probability that any respondent prefers one alternative over another is the probability that the utility of the preferred alternative is greater than the utility of the other alternatives as shown in equation (1). The probability of individual *i* choosing alternative *j* over alternative *h* from choice set C_i is shown in equation (1).

$$P(j|\mathrm{C_i}) = P\left[\left(V_{ji} + e_{ji}\right) > \left(V_{hi} + e_{hi}\right)\right] \tag{1}$$

For both models the error terms (e_{in}) are assumed to be independently and identically distributed with an extreme value (Gumbell[1]) distribution:

$$P(e_{in} \le t) = \mathrm{F(t)} = \exp\left(-\exp(\mathrm{t})\right) \tag{2}$$

Based on McFadden (1973), if the error term is distributed as above, the probability of any specific alternative *g* being chosen can be expressed in terms of the logistic distribution known as the conditional logit model:

$$P\left[\left(U_{ig} > U_{ih}\right)\forall h \neq g\right] = \frac{\exp(\mu \mathrm{V}_{in})}{\sum_{\mathrm{j}} \exp(\mu \mathrm{V}_{in})} \tag{3}$$

Where μ, is a scale parameter, inversely proportional to the standard deviation of *e*, usually assumed to be one. For estimates from choice modelling using the basic multinomial logit model to be statistically valid the conditions of independent and identical distributions (IID) and independence of irrelevant alternatives (IIA) must be met (Hanley et al., 2001).

The model can be estimated using the standard maximum likelihood function shown in equation (4) where y_{ij} is an indicator variable which takes a value of 1 if respondent *i* chooses option *j* and zero otherwise:

[1] Also known as Weibull

$$\log L = \sum_{i=1}^{N} \sum_{j=1}^{J} yij \ \log \left[\frac{exp(Vij)}{\sum_{j=1}^{J} exp(Vij)} \right] \quad \textbf{(4)}$$

WTP or WTA are then calculated based on the marginal rate of substitution between attributes. Thus choice modelling has the flexibility to model complex tradeoffs between alternatives, attributes and levels (Adamowicz et al. 1993; Rolfe & Bennett 2006b).

Choice models provide a richer data set than CVM because of the multiple choices available and with careful design the results will be robust and statistically defensible. However, framing the questions with sufficient background and contextual information to enable respondents to make an informed choice must always be balanced against imposing such cognitive strain on respondents that they may resort to decision heuristics or other short cuts which do not reflect actual preferences. This is particularly important when a choice experiment involves a product or situation which is unfamiliar to the respondents such as the case of carbon offset trading.

Both contingent valuation and choice modelling have been criticised in the literature due to a variety of concerns including the demonstrated WTP-WTA gap (Bennett and Blamey, 2001), the embedded or ‘scope’ effect and potential for other types of hypothetical bias.

In choice modelling experimental design elements including orthogonality (independence), level balance (each level appears with equal frequency), minimum overlap (the attribute level is not repeated in the choice set) and utility balance (utility of each alternative within a set is theoretically equal) can have a significant impact on statistical validity and must be carefully considered (Alpizar et al., 2001).

1.3 Choice model

Objectives

While valuations of the supply of public goods typically involved fixed quantities, the potential supply of private goods can vary between suppliers.

The purpose of this research is to estimate a supply curve for carbon offsets, thus it is necessary to estimate both the supply price and how many units (hectares) landholders would supply (enrol) at a given carbon price. This reflects the hypothesis that there will be a difference between preferences when considering the per unit value and when considering the total change in revenue. At the time of designing this study most of the literature which recognises this two-step discrete – continuous choice framework were based on the WTA for energy (Mitchell and Carson, 1989) or water (Olmstead et al., 2007). There were very few studies to be found in the literature which framed WTA to supply environmental goods and services in this manner. One such study was Lohr and Park (1995) who used a contingent valuation study to examine enrolment in filter strip programs. However, the data for this study was taken from two previous studies Purvis *et al.* (1990) and Lant (1991) rather than from a choice model specifically designed to examine this question. These studies were also all based on contingent valuation methodology.

This study extends previous work by using the discrete-continuous framework coupled with choice modelling to model a complex decision regarding participation in a carbon trading scheme. Since this study was designed and the data collected the use of a discrete-continuous framework within choice modelling to examine questions about the supply of environmental services has increased (for example Ballweg, 2013; Ma et al., 2012).

Based on these objectives the choice modelling survey was designed to:

1. Quantify and disaggregate the factors driving landholders' decisions regarding the production of carbon offsets.

2a. Estimate the minimum payment a landholder would need to engage in producing carbon offsets and,

2b. Quantify the number of offsets a landholder would supply at that price

Framework and methodology

Based on current biophysical, economic and political limitations the most realistic options for providing carbon offsets in Australia are expected to be various forms of agroforestry and possibly soil carbon sequestration {Garnaut, 2011 #82}. At the time the CM was created the Australian policy environment included a carbon 'tax' on large businesses and the carbon farming initiative was being developed, however there were no protocols appropriate for the extensive grazing industry {Department of Climate Change and Energy Efficiency (DCCEE), 2010 #83}. Thus the scenarios used in the choice model were developed from the most likely possible options based on the available science and policy environment.

Respondents were given three scenarios: maintain status quo (grazing), to allow additional regrowth or to increase soil carbon. In the regrowth scenario landholders would have to cease clearing tree regrowth and manage the regrowth to reduce fire, pest and week risks. The soil carbon scenario involved changing grazing management practices to increase groundcover as a proxy for soil carbon sequestration. These carbon sequestration alternatives have been identified as the most likely potential sources of carbon offsets from grazing land in Queensland by the CSIRO (Eady et al., 2009), the Garnaut Review (Garnaut, 2011) and in the policy papers for the proposed CFI (Department of Climate Change and Energy Efficiency (DCCEE), 2010). Each alternative was described by four attributes; production impact, annual monitoring and reporting requirements, guarantee period and payment.

An example choice set is shown in Figure 1 and a summary of the attributes and levels used in the experiment is provided in Table 2.

For the regrowth option landholders would be required to commit to cease clearing regrowth and manage the plot of land to reduce the risk of fire, pest or disease damage to vegetation. For landholders preferring the soil carbon option the scheme required a commitment to engage in grazing management practices that improve land condition. Both options would require landholder to commit to these practices for a specific period of time and undertake both baseline measurement and regular monitoring of carbon levels. Each carbon contracts was to be for a 50 hectare plot of land. The carbon contract would be attached to the land title so any change of ownership would result in a change of ownership for the carbon contract as well. The new owner would be required to either maintain the carbon contract for the period of the original contract or purchase carbon offsets to the value of those produced by the plot of land.

The landholder is assumed to maximize utility which is a function of the production returns from cattle, the availability of labour, the transaction costs of entering a carbon market, the value of carbon offsets, the certainty of the carbon market (measured by guarantee period), non-pecuniary benefits of cattle production and non-pecuniary benefits of producing carbon offsets. The decision to participate in a carbon offsets program can be modelled as a discrete choice to participate followed by a continuous choice to determine the number of units to be supplied. To assist in understanding the choices respondents were provided with additional information including photo standards which described the cattle and carbon production outcomes of each alternative.

This format allowed the following factors to be tested: the type of enterprise employed to sequester carbon, the change in productive capacity on the existing cattle production enterprise, the level of payment for carbon, the amount of monitoring required, length of contract and the impact of risk preferences.

Choice set design

Using the attributes and levels shown in Table 1 choice sets were constructed using an efficient[2] design. Prior utility estimates for the provision of carbon offsets were based on the results of previous experimental auctions and expert judgement. The choice set dimension was a three by four design. Each choice set contained three choices described by four attributes with four levels for each (except the production impact which had only three). An example of the choice sets is shown in Figure 1. The experimental design was constructed using NGENE with the final choice being a 12 set design. Twelve choice sets was deemed to be too many for each respondent and likely to induce status quo bias (Boxall et al., 2009) therefore the sets were divided into two blocks of six choice sets which were alternated between respondents. The efficiency statistics for the design are shown in Table 1.

Table 1 Choice model efficiency statistics

	Fixed
D error	0.002571
A error	0.007598
B estimate	82.2713
S estimate	127.6052

Acknowledging the WTP-WTA gap this, the results of this study are presented only as WTA. Embedded or scope effects Kahneman and Knetsch (1992) and issues of hypothetical bias occur if the preferences indicated by respondents are not true values because the choice set presented does not reflect the full set of possible choices or respondents do not have a sufficient incentive to reveal their true values. To mitigate these issues the number of alternatives, attributes and levels in each choice set was limited to reflect a realistic number of choices while limiting the possibility of protest bids caused by cognitive burden (Boxall et al., 2009; Rolfe and Bennett, 2006). A briefing statement was provided to implore respondents to act as they would in reality, confidentiality was assured to remove any disincentive to answer accurately

[2] An efficient design is one which minimises the D-error

and debriefing question were also used after the choice sets to elicit reasons for zero bids (Blamey et al., 2000b).

If a voluntary carbon trading scheme existed, which of these choices would you prefer?					
Options	Production impact	Paperwork	Guarantee period	What is the value of each alternative?	Please tick
					
Status quo - Grazing 	None	Nil	N/A	Current income from cattle	
Allow additional regrowth (on 50 ha)  For more information click here	Reduced stocking rate over time	Low	10 years	$1000 upfront payment Annual payment of $30/ha ($1500/50ha) for carbon offsets	
Increase soil carbon (on 50 ha)  For more information click here	Likely improvement in production (carrying capacity)	High	5 years	$1000 upfront payment Annual payment of ($150/ha) $5000/50ha for carbon offsets	

Figure 1 Example choice set

Unlike most previous choice modelling studies respondents have control over both whether or not to participate in producing carbon offsets and if they do, how many carbon offsets to supply.

The question of whether or not to label alternatives has been scrutinised carefully in the stated preference literature with varying conclusions. Using labels has been shown to reduce hypothetical bias as it is possible to describe the alternatives in a way which more closely resembles the actual policy scenario (Blamey et al., 2000a). While there is a concern that labels may induce the use of decision heuristics (Blamey 2000, Doherty 2011), the scenarios used in the choice model were new and novel to most respondents and each of the alternatives had significantly different implications for productivity of both the current enterprise and the proposed carbon offsets enterprise. Labelled choice sets were used facilitate communication of key options and allow attributes levels to vary between alternatives.

Following the choice sets a series of debriefing questions were presented to refine reasons for particular choices.

In addition to the choice model section respondents were also asked a series of questions regarding demographics, risk preferences and enterprise characteristics. Respondents' attitudes to environmental policy and carbon trading were also measured so that any link between these attitudes and their enterprise choice could be tested. A combination of approaches was used to elicit the different types of information from respondents.

Respondents were targeted from broad-scale cattle producers in Australia. Recruitment was conducted via email, cattle industry events and newsletters and resulted 56 unique, fully completed survey responses using both the web-based and paper-based surveys (response rate of 34%). The lower than desired response rate from both methods may have been caused by the length and/or complexity of the survey, lack of time or respondents forgetting to return the completed paper-based survey. It also reflects the difficulty of engaging with agricultural producers and the continuing policy uncertainty regarding carbon at the time of the survey. Registered respondents in the web-based survey were sent a reminder if they had not completed the survey after two weeks but respondents in the paper-based survey were not reminded which may have lowered the return rate.

Table 2 Choice attributes and levels

Attribute	Description	Attribute levels	Alternatives applicable to
Impact on production	The expected change to baseline cattle production as a result of implementing biosequestration practices. Livestock carrying capacity is calculated as function of grass production which is a function of tree density, therefore as regrowth increases carrying capacity declines. Higher soil carbon levels are expected to increase soil health and fertility, thus increasing grass production. Respondents were expected to make their own estimation of the magnitude of change which would be expected to impact on their choice.	- *None*	*Status quo*
		- Reduced stocking rate over time	Regrowth
		- Possible increase in stocking rate over time	Soil
Carbon payment	Payment per tonne of carbon sequestered annually. Payment levels were based on the range of carbon prices which have been suggested in various studies and the proposed fixed price starting point for the Australian carbon price.	- *$0/tonne*	*Status quo*
		- $10/tonne	Soil and regrowth – varied between choice sets
		- $20/tonne	
		- $50/tonne	
		- $100/tonne	
Guarantee period	Under the proposed CFI contract length will be limited by the guarantee period which will be set by the Domestic Offsets Integrity Committee. The guarantee period refers to the period during which the measurement protocols used to quantify a carbon offset are considered valid. It is expected that technical assessments and measuring capability will improve over time; therefore offsets will need to be reassessed against current standards at set intervals. In an effort to remain consistent with the proposals under the CFI, the attribute for contract length was renamed and redescribed as the guarantee period. The levels for the guarantee period were chosen based on the original period proposed under the CFI (3 years), the revised period proposed by the CFI (5 years) and two longer periods (10 years and 20 years) which were deemed to be realistic based on other programs for the supply of ecosystem services.	- *NA*	*Status quo*
		- 3 years	Soil and regrowth – varied between choice sets
		- 5 years	
		- 10 years	
		- 20 years	
Monitoring and reporting	The amount of additional paperwork per year required to manage carbon offsets. Very few estimates are available on the amount of time required for annual monitoring and reporting of carbon offset activities. Based on discussions with natural resource management staff and a review of the time required for previous stewardship type programs the levels shown in Table 1.1 were chosen as being a realistic range of possible time required.	-None	*Status quo*
		- Level 1 – ½ day/year	Soil and regrowth – varied between choice sets
		- Level 2 – 1 day/year	
		- Level 3 – 3 days/year	
		- Level 4 – 5 days/year	

1.4 Results

Pooling the data from both survey methods revealed that the majority of respondents (39) were from Central Queensland (see Figure 2). Forty per cent of the respondents were aged between 36 and 45 years and 85 per cent between 26 and 55 years of age, which is consistent with the industry average (Australian Bureau of Statistics, 2011). Most respondents run between 1 000 and 5 000 head of cattle which is slightly higher than the industry average for agricultural enterprises which receive the majority of their income from beef (see Figure 3).

Responses to the preliminary and debriefing questions revealed that the majority of respondents have multiple motivations for investing and working in agriculture, the strongest being the lifestyle rewards (‘lifestyle’) and the freedom (‘freedom’) they have to make their own decisions (see Figure 4). However, financial rewards are also an important component as only 20 per cent would be willing to sacrifice income (‘lower $’) to maintain environmental values. These values are likely reflected in the responses to the debriefing questions which asked for preferences between offsets from regrowth or soil. Forty-three per cent indicated they would participate in a soil offsets program but only 23 per cent in a regrowth offsets program. The relatively high willingness to participate is not unexpected, despite the ongoing uncertainty about carbon offsets because 37 per cent of respondents identified themselves as risk seekers and 41 per cent believe that carbon offsets could be a positive means of diversifying income. The stronger negative response to the regrowth option reflects the win-loss structure of the regrowth options which results in lower cattle production capacity. The soil option is a win-win as it results in higher cattle production capacity even without payment for carbon offsets.

Respondents rated their level of knowledge and information on carbon offsets as about average (4 out of ten) while 53 per cent believe that climate change is likely.

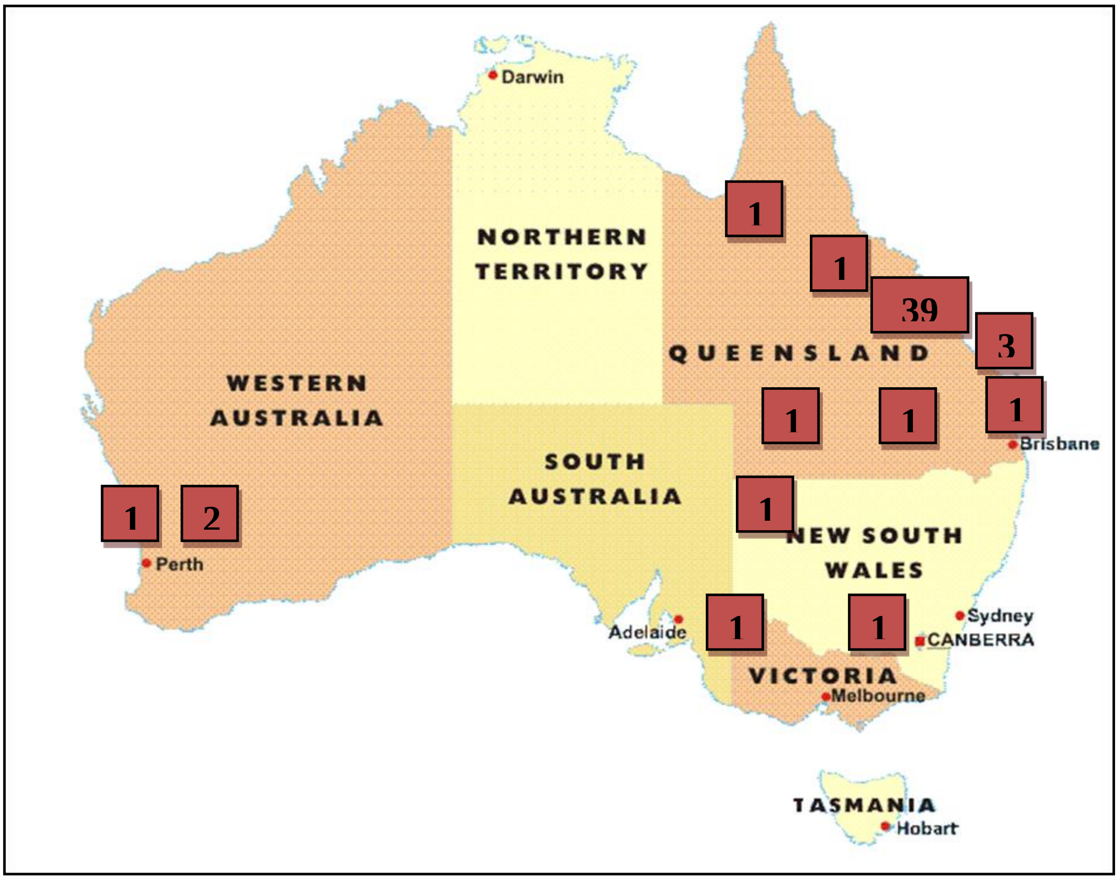
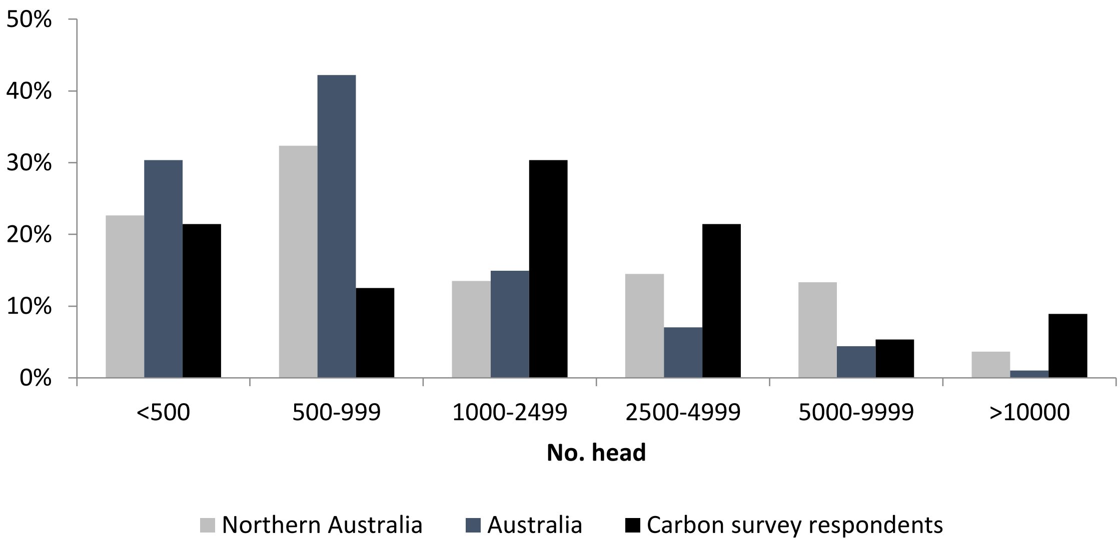


Figure 2 Survey respondent locations



***Data for Northern Australia and Australia from (ABS, 2009)**
Figure 3 Enterprise size

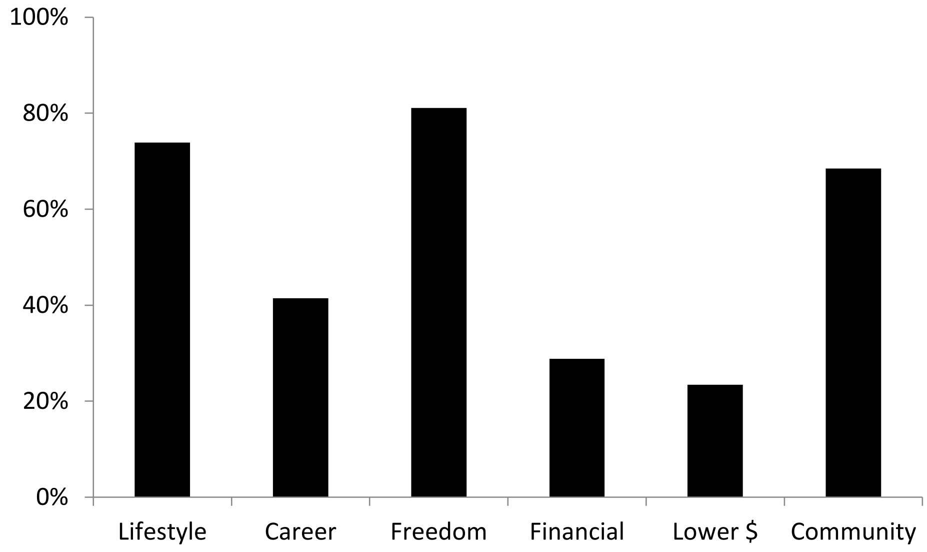


Figure 4 Respondents' motivations for farming

Choice model results

Testing for the drivers of participation rates in carbon offsets production

To address Objective 1 a Multinomial Logit (MNL) model was initially employed to estimate the marginal rates of substitution between attributes of the carbon offset scheme and to identify the significant landholder characteristics in determining participation in production of carbon offsets.

The MNL model had the following utility function. A description of each variable is listed in

Table 3.

$$U_{SQ} = \beta_1(Length) + \beta_2(Monit) + \beta_3(Cost) + \beta_4(Lower) + \beta_5(Risk) + \beta_6(Divers) + \beta_7(Labour) + \beta_8(Edu)$$

$$U_{Regrowth} = ASC_{regrowth} + \beta_1(Length) + \beta_2(Monit) + \beta_3(Cost)$$

$$U_{Soil} = ASC_{Soil} + \beta_1(Length) + \beta_2(Monit) + \beta_3(Cost)$$

Table 3 Descriptions of variables

Variable	Description
Payment	Payment per unit of carbon offsets
Monit	Number of days of additional paperwork to produce tradeable carbon offsets
Length	Length of contract (yrs) - based on the guarantee period
Lower	Respondent would accept a lower income to improve environmental values on their property (1 = strongly disagree, 5 = strongly agree)
Divers	Respondent believes that carbon offsets could be a good way of diversifying income (1 = strongly disagree, 5 = strongly agree)
Risk	Respondents risk preference (1 = highly risk seeking, 5 = highly risk avoiding)
Labour	Respondent believes that carbon offsets offer a way of reducing labour requirements (1= strongly disagree, 5 = strongly agree)
Edu	Level of education (1 = post graduate degree, 5 = high school)

The output of the MNL model as shown in

Table 4 indicates that two of the three carbon offset scheme attributes, payment and monitoring, are significant in determining participation. The variables for lower income, risk, diversification, and education and ASC_1 are also significant. The Alternative Specific Constants (ASC) capture the effect of unobserved utility such that the average probability for each alternative equals the proportion of respondents who actually choose the alternative (Blamey et al., 1999). In this model they capture the effects of the two labelled variables for the type of soil offsets being considered, regrowth or soil. The coefficient for ASC_2 (Soil) is higher than for ASC_1 (Regrowth) which suggests that landholders would require higher levels of compensation to enrol in a scheme to trade carbon from soil. This is likely a result of the perception that soil offsets are more risky, more variable and more difficult to measure. These results are supported by the subsequent tests reported below.

Table 4 Multinomial logit model

Multinomial logit model				Random Parameter Model			
Variable	Coefficient		Standard Error	Variable	Coefficient		Standard Error
BLENGTH	-0.017		0.013	BLENGTH	-0.059	**	0.026
BMONIT	-0.065	**	0.03	BMONIT	-0.087	**	0.038
BCOST	0.018	***	0.003	BCOST	0.023	***	0.004
BLOWER	-1.577	***	0.261	BLOWER	-1.855	***	0.342
BRISK	0.55	***	0.196	BRISK	0.624	**	0.258
BDIVERS	-1.208	***	0.233	BDIVERS	-1.329	***	0.302
BLABOUR	1.807	***	0.239	BLABOUR	2.135	***	0.311
BEDU	-0.205	*	0.109	BEDU	-0.314	**	0.141
ASC1 (Regrowth)	-1.397	**	0.688	ASC1 (Regrowth)	-1.427		0.892
ASC2 (Soil)	-0.063		0.67	ASC2 (Soil)	0.213		0.883
Adj R2	0.259		-	NsBLENGTH	0.14	***	0.031
				Adj R2	0.289		-

,**, at 10%, 5% and 1% significance level**

As expected, the coefficients indicate that respondents who are more risk averse would require a higher payment to adopt a carbon offsets enterprise but those who are more highly educated would be willing to participate at a lower price. The labour variable also has the expected sign on the coefficient, indicating that landholders who expect carbon offsets could be a viable means of reducing labour demands across the whole enterprise would participate in carbon trading at a lower price. However, the coefficients for the ‘Lower’ and ‘Divers’ variables do not have the expected sign. The negative coefficients on these variables suggest that landholders would be willing to accept a lower income in exchange for improved environmental values and those who see carbon offsets as a viable means of diversifying their enterprise income would actually require a higher carbon price to induce participation. It is possible that this outcome results from a misunderstanding of the question.

Alternatively, it may be that landholders who see carbon offsets as a viable means of diversifying their business are more business orientated and thus have a better understanding of the value of their current business and would require a substantial premium above that return to induce a switch. There is also a high degree of positive correlation in responses to both of these variables and participants’ age, education and risk aversion.

The Random Utility Model (RUM) which forms the basis of the MNL model assumes that preferences across individuals are homogenous, except where modified by factors such as age, education, or enterprise size (Rigby and Burton, 2005). However, based on the results of the survey and earlier results from the experimental auction, it is hypothesised that preferences amongst landholders for producing carbon offsets over maintaining their current agricultural enterprise may vary independently of the above-mentioned factors.

To test for this, a Random Parameters Model (RPL) was employed using the same utility functions as the MNL model. The RPL assumes that while the structure of the utility function is common across individuals, the parameters vary (Rigby and Burton, 2005). Using an RPL model provides several advantages over the MNL. In addition to explicitly accounting for the distribution of preferences across the population of respondents, the RPL model also explicitly accounts for the repeated choice structure (panel data) as presented to respondents in a choice survey. It also avoids the IIA issue.

The generic RPL model as defined by LIMDEP is:

$$f\left(y_{ij}\middle|x_{ij}, z_i\right) = g\left(y_{ij,}x_{ij,}z_i, \alpha_i\right)$$

Where $g(.)$ is the probability density individual, i, for choice, j.
y_{it} is the observed choice
x_{it} and z_i are measured covariates and,
α_i is an individual specific parameter vector that varies randomly between respondents with a mean of α and a covariance of Ω.

Two RPL models were run, the first randomising the payment variable and the second randomising Length. Using Length as the randomised variable was found to produce a more powerful model thus the results of that model are also shown in Table 4. By randomising Length, all three attribute variables become significant, however the ASC's are not significant. Despite this, the adjusted R-squared figure indicates the overall strength of the model. The coefficient for the random distribution (NsBLENGTH) is also significant which further suggests that there is significant variation in preferences between respondents and justifies the use of the RPL model.

One of the major advantages of MNL and RPL models is that multiple measures can be estimated from the same data set. A further measure which can be made is welfare estimates, which in this case indicate the amount of additional compensation landholders would require to produce a certain level of carbon offsets based on unit changes in contract attributes (referred to as part-worths). These values are consistent with the requirements of cost benefit analysis (Blamey et al., 2000b) which is useful for policymakers as they can be used to estimate the costs and benefits of developing the institutions needed to operate markets for environmental goods and services and the likely direct costs of procuring those services. If only changes in two variables are involved the value for changes in a single attribute (a ‘part-worth’) can be estimated by:

$$W = \frac{\lambda\beta}{\lambda\beta_{\$}} \qquad \textbf{(5)}$$

(Rolfe et al., 2002)

The results of applying equation (5) to the MNL and RPL models are shown in Table 6. The MNL model suggests that for every one unit increase in carbon offset contract length (year) or monitoring requirements (day), a landholder would demand on average an additional \$0.93 and \$3.57 per 50 acre block, per year, respectively. For the RPL model the figures are \$2.60 and \$3.87, respectively. Given the demonstrated (for example Whitten et al., 2008) and anecdotal evidence that onerous management requirements are a barrier to participation in environmental conservation schemes, the greater level of compensation demanded for greater monitoring compared to increased contract length is not unexpected.

The willingness to accept figures are fairly similar between the MNL and RPL models.

For both models the part-worths for a unit change in contract length or monitoring requirement indicate relatively modest demands for an increase in payment which is in contrast to the experimental auction results which suggested that increases in contract length would have a greater impact on required payment level than monitoring requirements. However, the method of estimating change WTA in the experimental auctions was subjective and not measured in the same scale for each attribute.

Table 6 Welfare estimates

MNL model				**RPL Model**			
	WTA	Lower bound	Upper bound		WTA	Lower bound	Upper bound
Length	$0.93	-$0.44	$2.66	Length	$2.60	$0.38	$4.94
Monitoring	$3.57	$0.23	$7.39	Monitoring	$3.87	$0.50	$7.46
ASC1	$76.89	$1.57	$154.29	ASC1	$63.24	-$15.54	$144.37
ASC2	$3.45	-$78.99	$78.42	ASC2	-$9.46	-$89.80	$69.86

These results provide a clear signal to policymakers that careful consideration needs to be given to the design of carbon contracts in terms of the monitoring and management requirements. To achieve sufficient participation to make a large scale program cost effective may require policymakers to accept a lower level of monitoring that would be considered optimal. If this is not palatable, more work will be required to develop systems that make the required levels of monitoring simpler for the landholder.

Following the presentation of the choice sets, respondents were asked to indicate how many plots of 50 hectares they would be willing to enrol in a carbon supply program. On average landholders indicated that they would supply 1.33 plots (66.5 hectares) of carbon for regrowth offsets and 1.55 plots (77.5 hectares) for soil carbon offsets. These figures represent less than two per cent of the average size of cattle properties in the initial case study area. This suggests strongly that the landholders would insist on trialling carbon offsets on a small area of land before switching a large portion of their property to this alternative enterprise.

1.5 Discussion and Conclusion

The purpose of this experiment was to determine whether using a stated preferences method could provide sufficient insight into landholders' preferences for supplying carbon offsets. The data collected was able to produce strong models which showed which contract and landholder attributes were specifically responsible for influencing adoption. Importantly, the results provide the first robust function for determining carbon supply from extensive beef production areas. Further refinement could be achieved a solid base for further analysis has been achieved.

In terms of the drivers of participation, the results showed that the financial value of providing carbon offsets is important to landholders but it forms only one component of the motivation for participation. Similar to Jaeck (2009) and Dupraz (2003) the results of this study demonstrate that landholders' risk preferences and their philosophy towards environmental conservation have a significant impact on their WTA. The implication of this result is that the most efficient policy will require heterogeneity rather than a one-size-fits-all approach. It also suggests that there are some landholders who may be unlikely to sign up to any carbon supply contract, no matter the amount of compensation offered.

In addition to estimating the actual supply of carbon offsets the choice model was designed to measure the impact of behavioural patterns and contract design characteristics on preferences for the provision of environmental services.

The results of the carbon CM indicate that context, both in terms of contract conditions and the policy environment impact significantly on the behaviour of landholders in relation to their decisions to supply environmental goods and services. Despite the ongoing discussion around carbon trading there is still no large scale carbon offset programs operating for agricultural lands in Australia. The choice sets asked the landholders to base their preferences for supplying carbon offsets on units of 50 hectares. The average area that landholders indicated they would enrol for the supply of regrowth or soil based carbon offsets (66.5 hectares and 77.5 hectares respectively) represent only 1.65 percent to 1.93 percent[3] of the average size cattle property in the Fitzroy Basin where the study was originally designed. Given the importance of trialability (Pannell et al., 2006) for adoption it is possible that (some) landholders were indicating their preferences for trialling the supply of carbon offsets on a small portion of their total landholdings. These results fit with the results of the experimental auction which indicate a level of reluctance amongst landholders to commit a carbon offsets enterprise based on the currently available data.

Data from the survey questions outside the actual choice sets confirms that landholders often have multiple motivations governing their production decisions and not all of these are purely profit maximizing. The impact of loss aversion is also evident in the

[3] Average cattle property size in the Fitzroy Basin is 4,021 hectares ABS 2010. Agricultural Commodities, 2008-09. Canberra: Austalian Bureau of Statistics.

degree of risk aversion shown and the desire to continue with a known enterprise when there is a high degree of uncertainty surrounding an alternative, possibly higher returning enterprise.

The design of the choice models were carefully crafted to try to reduce the impact of bounded rationality by testing simplified 'real-world' examples with knowledgeable respondents. The success of the design is indicated by the high response rate and the low number of zero or protest bids[4]. The relatively modest levels of compensation required suggest that the endowment effect was also minimised although again, it is possible that landholders were basing responses on enrolling only a small area initially as a trial. In this context the endowment effect would have little impact because of the small portion of land that is being 'given up'.

The results indicated a slight preference for supplying offsets through regrowth rather than through soil. This could be due to several reasons. One, soil carbon is seen as riskier and less tangible, therefore more susceptible to changes in policy or contractual arrangements. It is also a possible indicator of inertia as adopting a carbon enterprise through regrowth requires a landholder stop doing something (clearing regrowth) while soil offsets will require a much more proactive approach through changing grazing management practices. The need for higher compensation for additional monitoring compared to a longer contract length is also a possible indicator of inertia as it would require a greater deviation from short term administration requirements. This is also possibly an indication of hyperbolic discounting if landholders are not accurately accounting for long term contract costs. Overall, the used of stated preferences can be deemed as success as the results can be used to design direct payments more specifically and target those landholders who are most likely to supply at an efficient price.

References

ABS 2009. 71210.1 Agricultural Commodities, 2008-09. Australian Bureau of Statistics

ABS 2010. Agricultural Commodities, 2008-09. Canberra: Austalian Bureau of Statistics.

[4] excluding the contingent valuation question

Alpizar, F., Carlsson, F. & Martinsson, P. 2001. Using choice experiments for non-market valuation. *Working Papers in Economics* Department of Economics, Goteborg University

Australian Bureau of Statistics 2011. Land Management and Farming in Australia, 2009-10. http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/BA3F0BF7FE21AE60CA2575C40025E6F9?OpenDocument

Ballweg, J. 2013. Discrete continuous choice model to determine participation in contractual biodiversity conservation by pastoralists in northern Australia. *International Choice Modelling Conference.* Sydney.

Bennett, J. & Blamey, R. (eds.) 2001. *The choice modelling approach to environmental valuation,* Cheltenham, UK, Northhampton, USA: Edward Elgar.

Blamey, R., Bennett, J., Louviere, J., M., M. & Rolfe, J. 2000a. A test of policy labels in environmental choice modeling studies. *Ecological Economics,* 32**,** 269-286.

Blamey, R., Gordon, J. & Chapman, R. 1999. Choice Modelling: Assessing the Environmental Values of Water Supply Options. *Australian Journal of Agricultural and Resource Economics,* 43(3)**,** 337-357.

Blamey, R., Rolfe, J., Bennett, J. & Morrison, M. 2000b. Valuing remnant vegetation In Central Queensland using choice modelling. *Australian Journal of Agricultural & Resource Economics,* 44(3)**,** 439-456.

Boxall, P., Adamowicz, W. L. & Moon, A. 2009. Complexity in choice experiments: choice of the status quo alternative and implications for welfare measurement*. *Australian Journal of Agricultural and Resource Economics,* 53(4)**,** 503-519.

Department of Climate Change and Energy Efficiency (DCCEE) 2010. Design of the Carbon Farming Initiative: Consultation Paper. *In:* Department of Climate Change and Energy Efficiency (ed.). Canberra, Australia: Commonwealth of Australia.

Dupraz, P., Vermersch, D., Henry de Frahan, B. & Delvaux, L. 2003. The environmental supply of farm households. *Environmental and Resource Economics,* 25(2)**,** 171-189.

Eady, S., Grundy, M., Battaglia, M. & Keating, B. 2009. An analysis of greenhouse gas mitigation and carbon biosequestration opportunities from rural land use. CSIRO

Garnaut, R. 2011. Transforming rural land use. *Garnaut Climate Change Review - Update 2011*,Commonwealth of Australia

Hanley, N., Mourato, S. & Wright, R. E. 2001. Choice modelling approaches: A superior alternative for environmental valuatioin? *Journal of Economic Surveys,* 15(3)**,** 435-462.

Horne, P. 2006. *Forest owners' acceptance of incentive based policy instruments in forest biodiversity conservation – a choice experiment based approach.*

Jaeck, M. & Lifran, R. 2009. Preferences, norms and constraints in farmers' agro-ecological choices: case study using a choice experiments survey in the Rhone River Delta, France. *National conference of the Australian Agricultural and Resource Economics Society.* Cairns, Queensland.

Kahneman, D. & Knetsch, J. L. 1992. Valuing public goods: the purchase of moral satisfaction. *Journal of Environmental Economics & Management,* 22**,** 57-70.

Kahneman, D., Knetsch, J. L. & Thaler, R. H. 1991. Anomalies: The endowment effect, loss aversion and status quo bias. *The Journal of Economic Perspectives,* 5(1)**,** 193-206.

Knetsch, J. L. 1989. The endowment effect and evidence of nonreversible indifference curves. *American Economic Review,* 79(5)**,** 1277-1284.

Lant, C. 1991. Potential of the Conservation Reserve Program to control agricultural surface water pollution. *Environmental Management,* 15**,** 507-18.

Lohr, L. & Park, T. A. 1995. Utility-consistent discrete-continuous choices in soil conservation. *Land Economics,* 71(4)**,** 474.

Ma, S., Swinton, S. M., Lupi, F. & Jolejole-Foreman, C. 2012. Farmers’ Willingness to Participate in Payment-for-Environmental-Services Programmes. *Journal of Agricultural Economics,* 63(3)**,** 604-626.

Mitchell, R. C. & Carson, R. T. 1989. Using surveys to value public goods: the contingent valuation method. *Resources for the Future*

Olmstead, S. M., Michael Hanemann, W. & Stavins, R. N. 2007. Water demand under alternative price structures. *Journal of Environmental Economics and Management,* 54(2)**,** 181-198.

Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F. & Wilkinson, R. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture,* 46(11)**,** 1407-1424.

Plott, C. R. & Zeiler, K. 2005. The willingness to pay-willingness to accept gap, the "endowment effect," subject misconceptions, and experimental procedures for eliciting valuations. *The American Economic Review,* 95**,** 530-545.

Purvis, A., Hoehn, P. & Sorenson, V. 1990. Farmers' willingness to supply land as filter strips: Evidence from a Michigan survey. *In:* Napier, T. L. & Ankeny, I. A. (eds.) *Implementing the Conservation Title of the Food Security Act of 1985.* Soil Conservation Society of America.

Rigby, D. & Burton, M. 2005. Preference heterogeneity and GM food in the UK. *European Review of Agricultural Economics,* 32(2)**,** 269-288.

Rolfe, J. & Bennett, J. 2006. *Choice Modelling and the Transfer of Environmental Values,* Cheltenham, Edward Elgar.

Rolfe, J., Bennett, J. & Louviere, J. 2002. Stated values and reminders of substitute goods: Testing for framing effects with choice modelling. *Australian Journal of Agricultural and Resource Economics,* 46(1)**,** 1-20.

Shogren, J. F., Cho, S., Koo, C., List, J., Park, C., Polo, P. & Wilhelmi, R. 2001. Auction mechanisms and the measurement of WTP and WTA. *Resource and Energy Economics,* 23(2)**,** 97-109.

Whitten, S., Reeson, A. F., Windle, J. & Rolfe, J. 2008. Barriers to and opportunities for increasing participation in conservation auctions. *52nd Annual Conference of the Australian Agricultural and Resource Economics Society.* Canberra: Australian Agricultural and Resource Economics Society.