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Valuing the control of red imported fire ants in Australia using choice modelling

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Abstract

Invasive species create particular challenges for policy makers needing to identify and evaluate appropriate management responses. While some deliberately introduced species contribute significantly to agricultural production and other purposes, many invasive weed and animal pests have the potential to generate substantial costs through impacts on agricultural production, biodiversity, ecosystem services, infrastructure and communities. Red imported fire ants, an aggressive ant species, were introduced by accident to Australia, with infestations found in Brisbane in February 2001. Modelling suggested that the pest could invade half of Australia within 35 years if it was not controlled (Kompas and Che 2001; Scanlon and Vanderwoude 2006). While control efforts are reducing the rate of new discoveries, the pest had still not been eradicated by 2009. The benefits of controlling red imported fire ants are largely non-use benefits in terms of avoiding health impacts, maintaining lifestyle and amenity values, and avoiding environmental impacts. Accordingly, these benefits are assessed with an application of choice modelling, a non-market valuation technique.

Key words: Invasive species, red imported fire ants, choice modelling experiments, non-market valuation.

1. Introduction

Invasive species create particular challenges for policy makers needing to identify and evaluate appropriate management responses (Perrings *et al.* 2000; Born *et al.* 2005). While some deliberately introduced species contribute significantly to agricultural production and other purposes, many invasive weed and animal pests have the potential to generate substantial costs through impacts on agricultural production, biodiversity, ecosystem services, infrastructure and communities (Pimentel *et al.* 2005; Lovell *et al*. 2006). For example Pimentel *et al.* (2005) estimate that invasive species in the United States cost over US$138 billion per year in damages and control, while McLeod (2004) reports that the impact of invasive animals in Australia generates costs of more than AU$700 million annually.

In economic terms, efforts to control invasive species should be assessed by comparing the potential costs of the control against the benefits that may be generated, such as through the application of cost benefit analysis (Born *et al.* 2005; Burnett *et al.* 2008). Control efforts can be categorised into three broad groups. Prevention efforts such as quarantine protocols are aimed at preventing establishment, eradication measures can be applied at any time after establishment, and control measures are aimed at restricting spread at some point after establishment (Born *et al.* 2005). The justification for each of these measures, and the distribution of effort between measures should be based on the assessment of net benefits arising from the different options (Burnett *et al.* 2008).

There are several factors that complicate the application of a simple cost benefit framework (Born *et al.* 2005). First, biological invasions occur over space and time, and many benefits of control relate to the avoidance of future impacts and reducing the risks that impacts might occur. Second, there is a great deal of uncertainty about the current and potential impacts of biological invasions, making it difficult to assess impacts precisely (Burnett *et al.* 2008). This is complicated by the dynamic, non-linear growth patterns of most biological pests and the difficulties of predicting spread and impact over time (Perrings *et al.* 2000; Olson 2006). Third, many of the benefits of control are difficult to value, especially those involving reduced impacts on human health and the protection of environmental assets and ecological processes (Born *et al.* 2005; Lovell *et al.* 2006). Fourth, there are a large number of different invasive species, so both the costs and benefits of control often involve jointness and complementarities. Fifth, invasive species usually involve multidimensional and partial impacts (sometimes offsetting) (Pimentel *et al.* 2005), requiring net marginal impacts to be considered (Born *et al.* 2005). Sixth, impacts and the costs and benefits of control vary over locations, so it is not appropriate to assume uniform values across varied locations (Olson 2006).

Born *et al.* (2005) identify a number of deficiencies with the current pool of economic studies involving invasive species. Key research gaps include a lack of systematic valuation studies that assess non-use values, particularly those relevant to environmental impacts, a focus on ex-post evaluation instead of ex-ante studies, a focus on control measures instead of distinguishing between prevention, control and eradication options, and deficiencies in that uncertainty is rarely considered as an explanatory factor.

The focus of this paper is on valuing the benefits of controlling an invasive pest species, with a case study application to red imported fire ants in Brisbane, Australia. In this case study the benefits of controlling an invasion are assessed with an application of choice modelling, a non-market valuation technique. The application was framed to address the knowledge gaps specifically identified by Born *et al.* (2005). The paper is structured as follows. In the next section the underlying economic framework is described together with a review of previous studies in this field. An overview of the choice modelling technique is provided in section three, followed by a description of the case study and application of the experiment in section four. Experiment results are described in section five, and discussion and conclusions are presented in the final section.

2. Outlining the economic framework

Many public policy frameworks dealing with invasive species involve at least an implicit consideration of the benefits and costs of different control efforts or policy changes. An extended cost benefit analysis formalises this process, and is one of the key approaches that can be used in an economic evaluation of control options for invasive species (Born *et al.* 2005). The advantages of a cost-benefit study are that it attempts to be inclusive in terms of measuring all the outcomes of a proposed action, explicitly values the different impacts and outcomes, and provides a framework where very different outcomes may be assessed against each other. The methodical approach to the assessment of an issue offered in cost benefit analysis helps in the evaluation of issues, and can guard against rent-seeking behaviour by special interest groups.

A key stage in the analysis of environmental values is to categorise the types of benefits that might be associated with controlling or avoiding pest invasions (Born *et al.* 2005) (Figure 1).

Direct use values are benefits that directly accrue to individuals, and can be either extractive or non-extractive. Extractive use values include harvesting of natural resources like fishing and agriculture. Non-extractive values involve tourism, research and education.

Indirect use values include values that are gained indirectly from the natural resource, usually through support and protection of other economic activities. Examples include support to agriculture, fisheries, water quality, community lifestyles and indigenous culture.

Non-use values to society arise indirectly either through potential future uses or through the knowledge of the presence of the resource. These can be divided into option values, quasi option values, existence values and bequest values. Option values are values for use in the future, existence values are values for knowledge of their presence and bequest values arise from wanting to preserve the public good for future generations. Non-use values can be derived without any actual current human use of the resource.

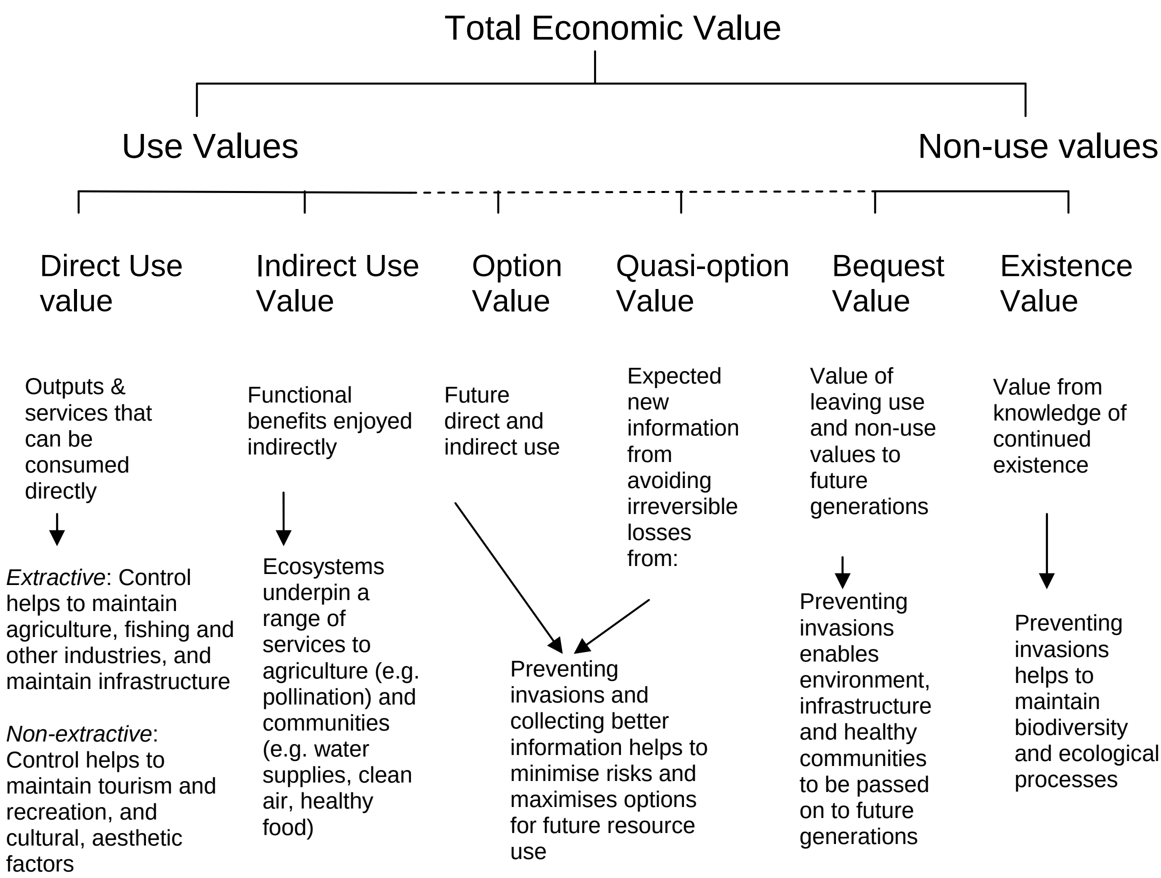


Figure 1 Total economic value and attributes of values for controlling invasive species

In many cases it is difficult to estimate each component of value as separate items. Under the Total Economic Value approach (Born *et al.* 2005), values arising from controlling an invasive species are either estimated jointly in a single valuation exercise, or values from separate estimation exercises are summed to give a total value estimate of the asset of interest.

Most efforts to value the benefits of controlling invasive species have focused on the extractive direct-use values, such as those associated with agriculture losses or treatment costs (Pimentel *et al.* 2005; Lovell 2006; Olson 2006). Some studies have involved the use of the travel cost method to estimate non-extractive use values for recreation that are affected by invasive species (Lovell *et al.* 2006). While direct and indirect use values are important for some types of invasive species, they rarely represent the total economic value, and may not be very significant for other invasive species. Other studies (e.g. Sinden and Griffith 2007) have focused on estimation of the costs of control and mitigation strategies as a weak proxy for the value that society assigns to avoiding invasive species. However estimation of values through replacement costs or defensive expenditures is unlikely to represent underlying community preferences for control, particularly where large non-use values are involved (Shogren *et al.* 2006).

A more comprehensive approach to valuing benefits of controlling invasive species requires the assessment of both non-use and use values. Non-use values can be assessed through the application of stated preference techniques such as the contingent valuation method or choice modelling. Applications involve people being presented with hypothetical scenarios about different options for resource management and the associated costs. Analysis of the preferred choices reveals how people would make tradeoffs between different environmental outcomes and the monetary tradeoff, allowing predictions of value to be made.

There has been very limited application of stated preference techniques to issues involving invasive species (Born *et al.* 2005; Lovell *et al.* 2006). Turpie *et al.* (2003) report estimates for the loss of existence values in the Cape Floristic Region in South Africa from invasive species using the contingent valuation technique. Numes and Van Den Burgh (2004) report the use of a joint travel cost study (to estimate recreation benefits) and a contingent valuation study (to estimate non-use benefits) associated with the removal of harmful algal-bloom species along the coast of The Netherlands. Champ *et al.* (2005) also apply continent valuation to assess the benefits of a weed control program in the United States of America. The only choice modelling study focused on weed control that could be identified is by Carlsson and Kataria (2008) who estimated benefits from a weed-control program in Sweden. and the United States of America respectively. Other studies have transferred benefit estimates from recreation, property, health or environmental valuation studies to infer the benefits of controlling an invasive pest species (Lovell *et al.* 2006).

3. The Choice Modelling technique

Choice Modelling (CM) is a stated preference technique where respondents are asked in a survey format to choose a single preferred alternative from a set of a number of resource use options (Bennett and Blamey 2001). The alternatives presented to respondents use a common set of underlying attributes that vary across different levels to create heterogeneity in choice sets. In some cases the alternatives are labelled to further differentiate between them. The attributes on offer and the different levels of each, together with any labels used, differentiate the options to respondents. By offering the combinations of attributes and levels in a systematic way through the use of an experimental design (Louviere *et al.* 2000; Bennett and

Blamey 2001), and then analysing the choices made, the key influences on choice can be identified.

The random utility approach underlying the CM technique provides the theoretical basis for integrating choice behaviour with economic valuation. In a Random Utility Model the probability of an individual choosing a good is assumed to be dependent on the utility of that good relative to the utility of alternative goods. That is, the probability that an individual *i* will choose alternative *j* in preference to alternative *h* is a function of attribute characteristics for the relevant good (represented by Z_{ij}), characteristics of the individual (represented by S_i), and an error (unexplainable) component (e_{ij}), as shown in the following formation:

$$P_{ij} = \text{Prob}[(\; _kZ_{ij} + \; _kS_i) - (\; _kZ_{ih} + \; _kS_i) > e_{ih} - e_{ij}] \quad \text{for all h in Choice set C, } j \quad h \qquad (1)$$

where $_k$ is a vector of utility coefficients associated with a vector of attribute and personal characteristics explanatory variables (Louviere 2001).

The parameters for the relationship can be introduced by assuming that the relationship between utility and characteristics follows a linear in the parameters and variables function, and by making specific assumptions about the distribution of the error terms. The multinominal logit (MNL) model is generally preferred because it is computationally easier to use (Louviere *et al.* 2000), and takes the general form:

$$P_{ij} = \exp(\; V_{ij})/ \; \exp(\; V_{ih}) \qquad \text{for all h in Choice set C, } j \quad h \qquad (2)$$

where represents a scale parameter which is commonly normalised to 1 for any particular data set. The MNL model generates results for a conditional indirect utility function of the form:

$$V_{ij} = \; (\; + \; _1Z_1 + \; _2Z_2 + ... \; _nZ_n + \; _aS_1 + \; _bS_2 + ... \; _mS_j) \qquad (3)$$

where is the constant term, $_1$ to $_n$ is the vector of coefficients attached to the vector of attributes (Z), and $_a$ to $_m$ is the vector of coefficients attached to the vector of socio-economic variables (S), that together influence utility. The constant term can be partitioned into alternate specific constants (ASCs) that are unique for each of the alternatives that are considered in the choice sets. These ASCs capture the influence on choice of unobserved attributes relative to specific alternatives, but also include residual modelling effects.

Welfare change estimates can be generated from MNL models through the use of the following formula:

$$CS = -1/ \; [\ln \; \exp V_{io} - \ln \; \exp V_{i1}] \qquad (4)$$

where CS is the compensating surplus welfare measure, is the marginal utility of income (generally represented by the coefficient for the monetary opportunity cost attribute in an experiment), and V_{i0} and V_{i1} represent indirect utility functions before and after the change under consideration. For continuous data, the marginal value of a change in compensating surplus within a single attribute can be represented as a ratio of coefficients, where equation 4 reduces further to:

$$W = -1x_{\text{attribute}} / _{\text{money}} \qquad (5)$$

This part-worth formula effectively provides the marginal rate of substitution between income change and the attribute in question.

The assumptions implicit in the use of the MNL model impose a restriction known as the Independence from Irrelevant Alternatives (IIA) condition. This states that the probability of a particular alternative being selected is independent of the other alternatives, and has an underlying condition that the error terms are independently and identically distributed (IID). To avoid these strict IIA/IID conditions, other forms of logit models have been developed, including nested logit models.

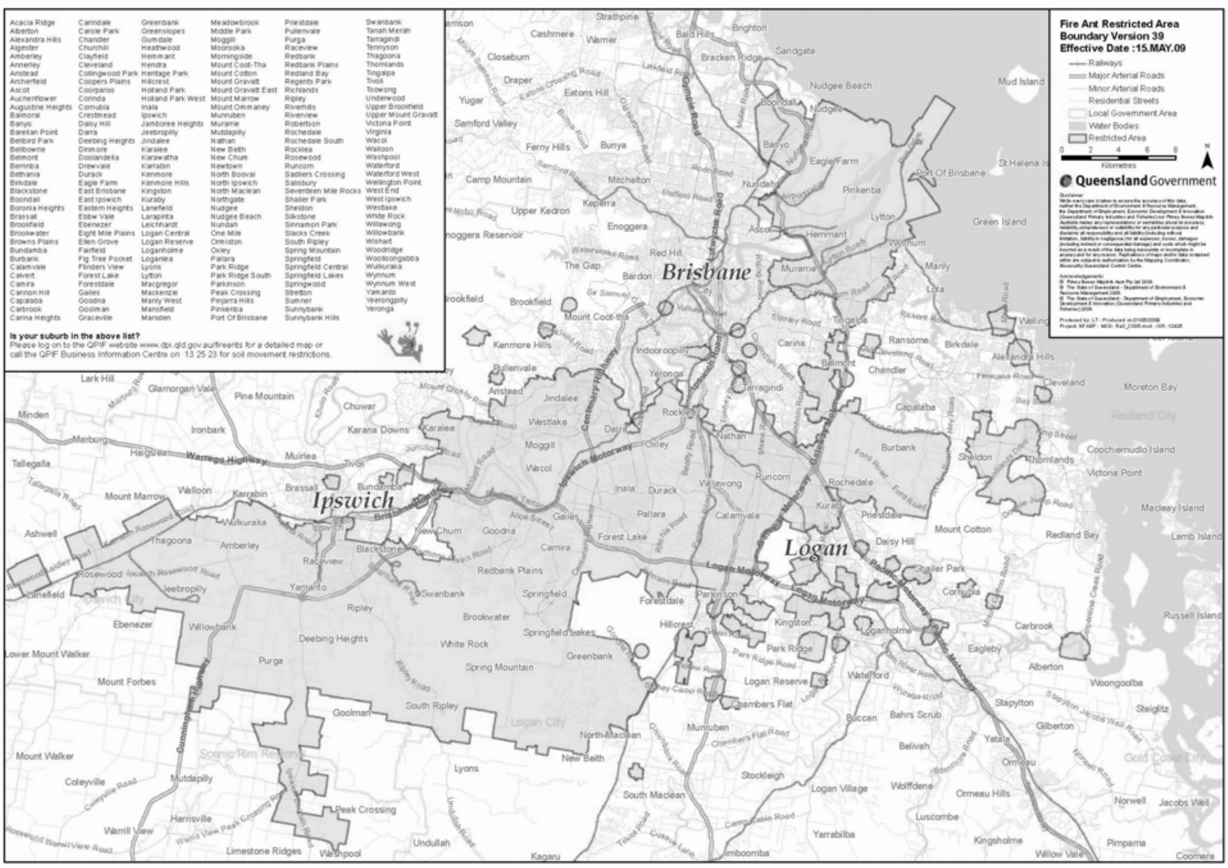
Nested logit allows the distribution of error terms to vary across groups (nests) of choices, essentially allowing the random error component to vary according to which group of choices respondents might select. For example, choices for conservation options may share similar error distributions, but may be very different to the error distribution for the ‘no support’ option. A nested model allows a decision pathway to be modelled, where respondents make an initial choice between ‘support/no support’, and, if they choose the ‘support’ branch, then a subsequent choice about which option is more attractive. An inclusive value parameter identifies the level of correlation that exists between the nested choices, and links the model together.

It is also possible to generate different models in choice experiments by relaxing assumptions about the homogeneity of preference construction (Louviere *et al.* 2000). One approach to allowing preference heterogeneity is the use of latent class models, where the population of respondents is partitioned into segments. The probability function that is estimated reflects the likelihood that respondents from a particular segment (latent class) will choose an alternative, and with different choice behaviour across groups (Louviere *et al.* 2000; Lusk and Schroeder 2004).

4. The case study: Red imported fire ants in Brisbane, Queensland

Red imported fire ants are an aggressive ant species that is native to South America and are viewed as a major risk to Australia for several reasons. It has detrimental impacts on human health, human lifestyle patterns, livestock and wildlife through its aggressive stings (Jetter *et al.* 2002). It may also have impacts on crops by feeding on sap, and on electrical equipment and infrastructure through nest building (Jetter *et al.* 2002; Morrison *et al.* 2004). The species now inhabits extensive areas in the southern United States, where it causes extensive damage, mostly through impacts on residential households (Scanlon and Vanderwoude 2006). There is potential for the species to colonise large areas of non-arid Australia if it is not controlled (Morrison *et al*. 2004; Scanlon and Vanderwoude 2006).

Red imported fire ants were introduced by accident to Australia, with infestations found in the port areas and south-western suburbs of Brisbane in February 2001 (Moloney and Vanderwoude 2002). Followup surveillance identified scattered infestations in more than 300 km^2 of the area (Scanlon and Vanderwoude 2006). Modelling suggested that the pest could invade half of Australia within 35 years if it was not controlled (Kompas and Che 2001; Scanlon and Vanderwoude 2006). The Queensland Government has led a vigorous eradication policy funded by the Australian and state governments to identify and control outbreaks[1], including regular inspections and control efforts, and restrictions over the movement of soil and garden waste in areas at risk (Figure 2). While control efforts are reducing the rate of new discoveries, the pest had still not been eradicated by 2009.



Source: Queensland Government, 2009

Figure 2 Red imported fire ant restricted area in Brisbane in May 2009

There were several reasons for choosing red imported fire ants as a case study, including the ability to address some of the knowledge gaps identified by Born *et al.* (2005). First, the benefits of controlling red imported fire ants are largely non-use benefits in terms of avoiding health impacts, maintaining lifestyle and amenity values, and avoiding environmental impacts (Moloney and Vanderwoude 2002). Second, it represented an ongoing pest incursion, where public and private effort continued to be invested. Third, there was high levels of awareness and knowledge of the pest, with few other competing pest issues in the region, making it easier to frame different control options to households. Fourth, a key management issue to address was whether government should pursue more expensive eradication strategies or

[1] More information can be found on the Queensland Government website: http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_4538_ENA_HTML.htm

have lower levels of control at reduced cost and inconvenience to the public. Fifth, uncertainty does exist about the future spread of the pest and the cost and effectiveness of measures to contain it, and it may be realistic to present some of that uncertainty to respondents.

Application of the choice modelling technique to the case study setting involved identifying the frame of the tradeoffs to be offered, the key attributes, levels and labels that were used to define the tradeoffs, and the way in which the payment vehicle was used to define the opportunity costs involved. The frame of the survey matched closely with the scenarios reported in Kompas and Che (2001), Scanlon and Vanderwoude (2006) and Anthony *et al.* (2009) where assumptions about no further control of fireants in Brisbane would lead to increasing levels of spread and infestation over the next 35 years. In the experiment, respondents were asked if they were willing to pay for ongoing control of red imported fire ants over the next 10 years to 2020 in order to avoid the impacts of future infestation.

Attributes used in the choice modelling experiment matched closely with the outputs of the biological spread models reported in Kompas and Che (2001) and Anthony *et al.* (2009). These focused on the potential levels of infestation in residential areas (private homes), public areas (schools and sporting areas) and environmental areas (native bushland). The attributes were designed to capture both use and non-use values associated with potential health, lifestyle and environmental impacts of red imported fire ants. Other potential impacts on agriculture and infrastructure were not included in the experiment, and respondents were informed that these impacts would be assessed separately. The levels for each attribute were predicted from the spread models reported in Anthony *et al.* (2009).

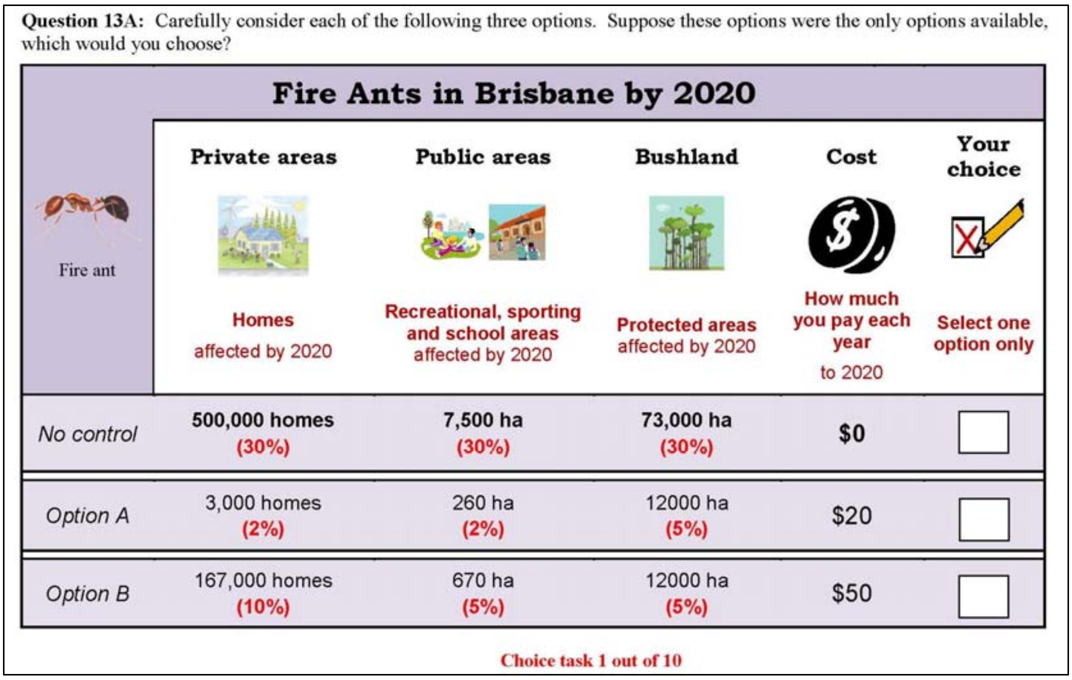
The cost mechanism chosen was an annual payment over ten years (to 2020). It was described to respondents in the following way:

> *Costs can include different combinations of private control costs, and rates, fees and taxes paid to government to cover public costs of control*

Defining the payment vehicle in a general way helped to encompass the different types of public and private costs that might be incurred, and was also likely to minimise protects against any specific type of cost mechanism. It also may have helped to make the costs relevant to different groups of respondents, including both home owners and renters.

The experiment was applied in a series of choice tasks, each with three alternatives where there was a common first option. The latter described a situation where there was no control program and no cost to individual taxpayers, but there would be a large level of pest invasion expected across the three attribute areas by 2020. The other two options involved much lower levels of impact, but had an associated payment to reflect the opportunity costs of control. An example of a choice set is shown in Figure 3.

There were three versions of the survey run in the same experiment. The first version (Figure 3) had three unlabelled alternatives, while the other two versions differed only in that the alternatives (Option A and Option B) were labelled. The second version identified whether an Eradication or Containment control strategy would be pursued by including those as labels. For this version, the experimental design was tailored slightly to show that the eradication policy tended to have higher cost levels but would result in lower levels of impact compared to a policy of containment. The third version involved labelling the alternatives as having High Certainty or Low Certainty that the controls would be effective, with the same attribute levels as used in the first version. Details of the descriptions for the labelled alternatives as well as the different attribute levels applied in the different versions are outlined in Table 1.



Note: Each choice set contained links to further information on fire ants and to background survey information

Figure 3 Sample choice set from the unlabelled Version 1

Table 1 Attribute and alternative label descriptions and levels

		Private areas[1]	**Public areas**[1]	**Bushland**[2]	**Cost**
Options	Description	No of homes affected by 2020	Recreational, sporting and school areas affected by 2020	Protected areas affected by 2020	How much you pay each year to 2020
All Versions					
Option 1	No control	500,000 homes (30%)	7,500 ha (30%)	73,000 ha (30%)	$0
Version 1					
Option 2 Option 3	Option A Option B	1%, 5%, 10%	1%, 5%, 10%	5%, 10%, 15%	$20, $50, $200
Version 2					
Option 2	**Containment** *(smaller control effort)*	2%, 5%, 10%	2%, 5%, 10%	5%, 10%, 15%	$20, $50, $100
Option 3	**Eradication** *(Larger control effort)*	0.5%, 2% 5%,	0.5%, 2% 5%,	5%, 10%, 15%	$50, $100, $200
Version 3					
Option 2 Option 3	**High certainty** **Low Certainty** *predictions are correct*	1%, 5%, 10%	1%, 5%, 10%	5%, 10%, 15%	$20, $50, $200

Note: Attribute levels were always described in terms of both an absolute amount and a percentage – only the percentages are recorded in this table.

[1] Information sourced from Anthony *et al.* 2009; [2] Included 10 Local Government Areas

The combination of attribute levels for the different options was determined using an efficient design created in the ©Ngene software program. The same experimental design was applied for versions 1 and 3 (D error = 0.0008) with a different one for version 2 (D error = 0.0026). The survey design was tested and refined with four focus groups (each with 8-10 participants) held with Brisbane residents during 2009. The final survey instrument involved five key sections:

- Background information to define the issues and refer respondents to further information if required,
- Collection of data about knowledge, attitudes and experience with red imported fire ants,
- A series of 10 choice sets and followup questions
- A contingent valuation survey about biosecurity (not reported in this paper), and
- Collection of data about respondent characteristics.

The survey was conducted in an online format with a private organisation employed to host the survey and to provide access to an internet panel of Brisbane residents. Three hundred and twenty nine respondents were surveyed from the Brisbane metropolitan area, with similar proportions answering each of the three versions. Fifty six percent of the respondents were living within a Fire Ant Restricted Area[2] and 44% were living outside the restricted area. The survey responses were collected in a three week period in August 2009.

There were some small differences between the sample group and the census data for the population. The average age of respondents, as well as the gender proportion, was in line with that from the general population (based on 2006 census data from the Australian Bureau of Statistics (ABS)) (Table 2). The average household income was slightly lower than that from the general population. The education of the respondent group was slightly higher than that of the general Brisbane population with 10% more having post-school qualifications and many more having Tertiary education.

Table 2 Respondent socio-demographic characteristics

	Sample Population	ABS Population
Average age (within the range sampled)	42.6	43
Proportion of females	52.0%	51.4%
Proportion of households with children	38%	
Education:		
Post-school qualification	59.3%	49.0%
(Tertiary education)	(42.5%)	(29.5%)
Average household income	$62,665	$66,112

The majority of respondents were long term residents of Brisbane, with close to 60% of people living in the area for 15 years or more. Two thirds of residents intended to stay in the city for at least the next 10 years, with over half intending to stay the rest of their lives. Most respondents lived in houses, with more than 50% owning their homes. Nearly 90% of respondents had access to a yard or garden, with 70% of them using the space often or very often.

[2] As defined by the Queensland Government dated 15 May 09. (http://www.dpi.qld.gov.au/)

5. Values for reducing the spread of red imported fire ants

The focus of the choice modelling experiment was to estimate values for reducing the risks of damages from red imported fire ants. In line with the recommendations of Born et al. (2005), the experiment also tested if values were sensitive to respondents living in a control area for the pest, the type of strategy pursued (control versus eradication), and the level of certainty associated with the intervention outcomes. The survey data indicated that the broad framing of the choice experiment was likely to be appropriate. Respondents were generally aware of red imported fire ants in Brisbane (88%), with two-thirds (66%) concerned about the impact on themselves and their community. There was limited confidence that the pest species could be eradicated, with only 4% fully confident that the species would be eradicated (Figure 4). This confirms that the choice scenarios with differing levels of future infestation dependent on the control strategies undertaken were likely to be viewed as realistic.

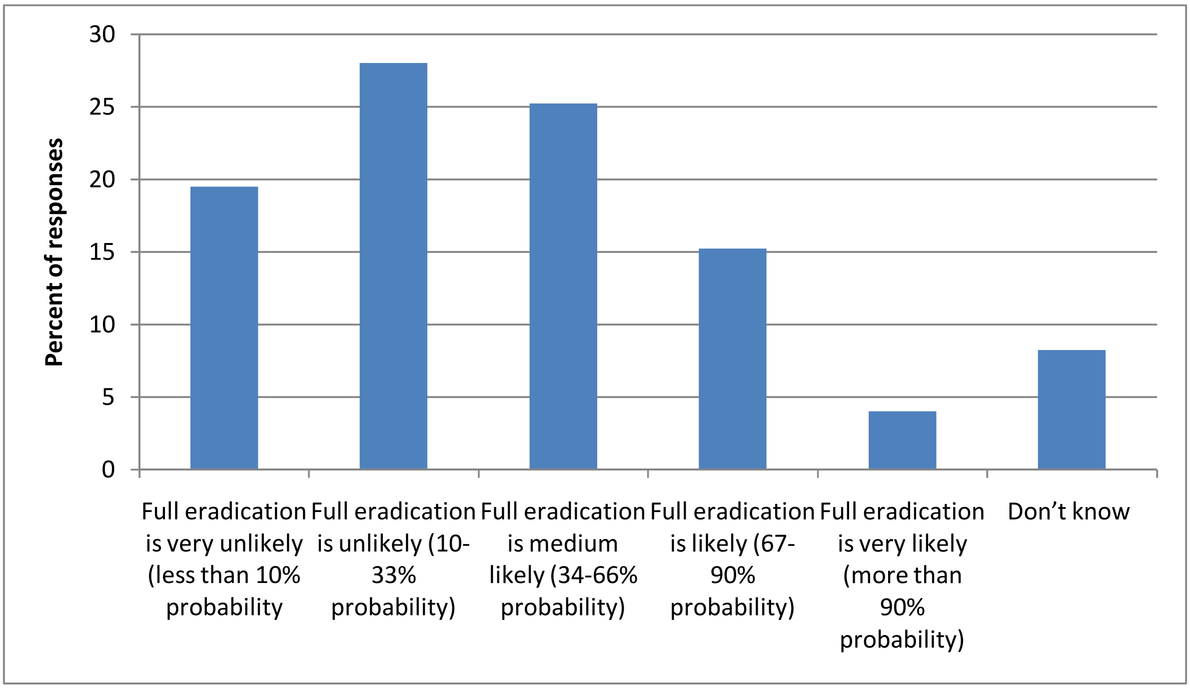


Figure 4 Level of confidence that red imported fire ants can be eradicated

In the experiment, each respondent completed 10 choice sets, with the first discarded as a practice used for familiarisation. Across the 329 respondents, this generated a total of 2,961 choice sets over the three versions. The results were modelled in Limdep and descriptions of the variable used in the following models are presented in Table 3.

Nested choice models generated more appropriate model fits than MNL model specifications. In the nested model, respondents were assumed to first make a choice about whether to support a control alternative (at a cost) or not, depending on a number of respondent characteristics and a constant term to capture the contribution of other non-specified attributes. Respondents who chose a control strategy were then assumed to choose between the two alternatives by considering the attributes and levels. The results for this formulation of the choice model are shown in Table 4.

Table 3 Model variable descriptions

Variables	Description
Cost	Amount households pay each year to 2020
Private areas	% + no of homes (private areas) affected by RIFA
Public areas	% + ha of public areas (recreational, sporting and school areas) affected by RIFA
Bushland	% + ha of bushland (protected areas affected by RIFA)
Age	Age of respondents in years
Gender	1= male; 2= female
Children	1= children living in the household; 0=no children
Education	Education coded in categories as presented in the survey from 1= primary only to 5= tertiary degree or higher
Income	Income coded in categories as presented in the survey from 1= less than $33,000 per year to 5= more than $104,000 per year
RIFA area	1=living in a RIFA restricted area; 0=not
ASC_no control	Constant with the "no control" Option 1
ASC_Option 2	Version 2 label = Containment Strategy; Version 3 label = High Certainty
ASC_Option 3	Version 2 label = Eradication Strategy; Version 3 label = Low Certainty
High Certainty	Dummy coded for selection of High Certainty option
Eradication Policy	Dummy coded for selection of Eradication Policy option

Table 4 Nested choice model across pooled data set

Attributes	Coefficient	Standard error	Part worths per household
Cost	-0.0096***	0.0007	
Private areas	-0.0553***	0.0098	$5.79 (per 17,000 houses)
Public areas	-0.0287***	0.0089	$3.01 (per each 150 ha)
Bushland	-0.0464***	0.0068	$4.86 (per 2,400 ha)
Socio- demographic attributes associated with the "no control" Option 1			
Age	-0.0265***	0.0039	
Gender	-0.4435***	0.1088	
Children	0.3358***	0.1077	
Education	-0.1528***	0.0506	
Income	-0.2759***	0.0426	
RIFA area	0.5758***	0.1124	
ASC_ No control	4.2471***	0.5837	
IV parameter:			
No Pay	1		
Pay	0.6082***	0.0972	
Model statistics			
No of observations	2961		
Log Likelihood	-2774		
Adjusted rho-square	0.2669		
Chi-square (D of F)	2036 (13)		

*** = significant at the 1% level

Model fit is strong, as indicated by the chi-square and adjusted rho-square statistics. The IV parameter is highly significant, confirming that respondents were likely to adopt a two-stage decision process in choosing between alternatives. Most coefficients are signed as expected. The negative coefficients for the attributes confirm that respondents prefer to avoid higher levels of cost or increasing infestation levels in housing, public areas and bushland. Respondents who chose not to support control options were more likely to be younger, male, have lower levels of education and have lower income. Respondents from outside the control areas were more likely to select increased protection options, indicating that this group may have a premium for remaining outside infested areas. Unexpectedly, respondents from households with children were more likely to choose the 'no control' option.

Part-worths for the model have been calculated with Equation 5, and show the willingness to pay for each one percent improvement for each attribute. The results show that the average householder is willing to pay $5.79 for each 17,000 houses protected, $3.01 for 150 hectares of school and sporting fields protected, and $4.86 for each 2,400 ha of bushland protected.

To identify the influence of the labelled alternatives when data for the second and third versions of the survey were pooled, it was necessary to combine the three non-cost attributes into a single 'average infestation level'. A conditional logit model that predicted choice in terms of alternative labels, cost and an average infestation level is shown in Table 5. As in the nested models, respondent characteristics are modelled to predict the likelihood that a 'no control' option will be taken. The results show that respondents prefer the alternatives that have high certainty of outcomes or have an eradication focus. The willingness to pay for high certainty options was an additional $94 per annum plus $0.71 per annum for each additional 1% of area protected, while the willingness to pay for eradication strategies was an addition $117 per annum plus $0.71 per annum for each additional 1% of area protected. These values demonstrate to policy makers the importance of improving certainty of outcomes and targeting eradication options.

Table 5 Conditional logit model with dummies for key alternatives

Attributes	Coefficient	Standard error	Part worths per household
Cost	-0.0085***	0.0007	
Average infestation	-0.0006*	0.0036	$0.71 (per 1% of area protected)
High Certainty	0.8091***	0.0742	$94.00 (for high certainty options)
Eradication policy	0.9973***	0.0809	$117.00 (for eradication options)
Socio- demographic attributes associated with the "no control" Option 1			
Age	-0.0389***	0.0055	
Gender	-0.4925***	0.1445	
Children	0.2207	0.1429	
Education	-0.4100***	0.0698	
Income	-0.2759***	0.0576	
RIFA area	0.5634***	0.1482	
ASC_ No control	8.3369**	3.2627	
Model statistics			
No of observations	2025		
Log Likelihood	-1749		
Adjusted rho-square	0.125		

*** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level

The information about respondent choices can be further enhanced by identifying different groupings of preferences with latent class models. This identifies separate parameter estimates, and hence values, for sub-groups within the respondents. Three latent classes were identified with the model (Table 6). The results indicate that latent class 1, representing approximately 23.5% of respondents, has very high values for protection, especially for private homes. Latent class 2, representing approximately 63% of respondents, has moderate values for protection for all attributes, while latent class 3, representing approximately 13% of respondents, had negative values for protecting houses. It is expected that this latter group were focused on the potential costs involved.

Table 6 Latent Class model across pooled data set.

Attributes	Coefficient	Standard error	Part worths per household
Latent Class 1			
Estimated probability	0.2349***	0.0204	
Cost	-0.0141***	0.0040	
Private areas	-0.3927***	0.0369	$27.85 (per 17,000 houses)
Public areas	-0.2092***	0.0328	$14.84 (per 150 ha)
Bushland	-0.1725***	0.0187	$12.23 (per 2,400 ha)
Latent Class 2			
Estimated probability	0.6327***	0.0869	
Cost	-0.0141***	0.0003	
Private areas	-0.0569***	0.0058	$4.04 (per 17,000 houses)
Public areas	-0.0525***	0.0064	$3.72 (per 150 ha)
Bushland	-0.0259***	0.0056	$1.84 (per 2,400 ha)
Latent Class 3			
Estimated probability	0.1324***	0.0191	
Cost	-0.0141***	0.0003	
Private areas	0.0528**	0.0233	-$3.74 (per 17,000 houses)
Public areas	0.0192	0.0233	Not significant
Bushland	-0.0085	0.0260	Not significant
Model statistics			
No of observations	2961		
Log Likelihood	-2144		
Adjusted rho-square	0.3397		
Chi-square (D of F)	2219 (12)		

*** = significant at the 1% level, ** = significant at the 5% level

6. Conclusions

The research reported in this paper has focused on the potential for stated preference techniques such as choice modelling to assess values for preventing or addressing outbreaks of invasive species. Benefit estimates are required to perform more systematic analysis of intervention strategies in frameworks such as cost-benefit analysis. However, there is a current lack of studies that estimate benefits involving non-use values, such as those impacting on communities and the environment. Given the range of invasive species that have major non-commercial impacts, a demonstration that stated preference techniques can address these information gaps is important.

The case study application to red imported fire ants in Brisbane, Australia, has addressed several of the information gaps identified by Born *et al*. (2005). A key contribution is that the research demonstrates significant values exist to address future risks of infestation. These values are likely to encompass both non-use and use factors relating to protection of private homes, public spaces (schools and sporting areas) and bushland in the regional area.

The case study shows that prevention values are higher for people outside (but adjacent to) protected areas, confirming that values exist to avoid future problems. There are significant values for pursuing an eradication program for red imported fire ants rather than simply controlling them, and higher values associated with programs that generate high certainty of results. However, significant heterogeneity in responses could be identified, with different groups of respondents having very different value sets. This information will help policy makers to evaluate different management options, and engage in the political economy of generating support and providing information back to communities.

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