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# 1 A Stated Preference Valuation of the Non-Market Benefits of 2 Pollination Services in the UK

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## 4 **Abstract**

5 Using a choice experiment survey this study examines the UK public's willingness to pay to  
6 conserve insect pollinators in relation to the levels of two pollination service benefits: maintaining  
7 local produce supplies and the aesthetic benefits of diverse wildflower assemblages. Willingness to  
8 pay was estimated using a Bayesian mixed logit with two contrasting controls for attribute non-  
9 attendance, exclusion and shrinkage. The results suggest that the UK public have an extremely  
10 strong preference to avoid a status quo scenario where pollinator populations and pollination  
11 services decline. Total willingness to pay was high and did not significantly vary between the two  
12 pollination service outputs, producing a conservative total of £379M over a sample of the tax-paying  
13 population of the UK, equivalent to £13.4 per UK taxpayer. Using a basic production function  
14 approach, the marginal value of pollination services to these attributes is also extrapolated. The  
15 study discusses the implications of these findings and directions for related future research into the  
16 non-market value of pollination and other ecosystem services.

## 17 **1. Introduction**

18 Pollination, the transfer of pollen within and between flowers by insect vectors is a key  
19 ecological function facilitating reproduction in 78% of temperate flowering plants (Ollerton et al,  
20 2011). These plants underpin the function of a range of ecosystem services, such as food crop  
21 production (Klein et al, 2007), soil quality, pest regulation (Sarrantonio, 2007) and improving  
22 landscape aesthetics (Lindemann-Matthies et al, 2010). At present, populations of both wild and  
23 managed pollinating insects within the UK have experienced substantial long-term declines (Potts et  
24 al, 2010; Carvalheiro et al, 2013), raising concerns about the stability of pollination services. As a  
25 regulatory, or intermediate, ecosystem service (Fischer et al, 2009), pollination has typically been  
26 valued as a component of the final benefits it provides (but see Allsopp et al, 2008). To date only the  
27 benefits to crop markets have been economically quantified to assess the value of production  
28 changes resulting from pollination services to crops (e.g. Winfree et al, 2011). Unlike crop  
29 production, other final benefits of pollination services are not directly traded on markets and are  
30 often public (they are not owned by anyone exclusively) and non-excludable (people cannot be  
31 prevented from using them) (Cooke et al, 2009). Furthermore, there may be intrinsic values attached  
32 to the existence of pollinators (e.g. Mwebaze et al, 2010). As valuation is often used to underpin  
33 decision making, an exclusive focus on market benefits will neglect the broader impacts such  
34 decisions can have on wider stakeholders.

35 In order to redress the failure of markets to capture the benefits of non-market ecosystem  
36 services, economists have exploited a range of techniques, broadly categorized as revealed or stated  
37 preference methods. Revealed preference methods utilise existing market or experimental data to

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38 estimate previously uncaptured benefits arising from ecosystem services (e.g. hedonic price models  
39 used to value the benefits of proximity to natural habitat on house prices; Hanley et al, 2007). Stated  
40 preference methods create a hypothetical market for environmental goods/services using a  
41 questionnaire or interview and ask respondents to state preferences for bundles of these  
42 goods/services. Costs attached to each bundle act as a price within the market, allowing estimation  
43 of respondent willingness to pay (WTP) to acquire or maintain the goods/services or their willingness  
44 to accept (WTA) compensation for their degradation of the goods/services if the costs are negative  
45 (Bateman et al, 2002), Stated preference allow a wide range of respondent factors to be modelled  
46 and compared and, unlike revealed preference techniques, are theoretically applicable to any  
47 ecosystem service (Hanley et al, 2007). Stated preference methods are based upon random utility  
48 models which assume that respondents are rational, self-serving utility maximisers who will express  
49 preferences that optimise their utility (Train, 2003). However, recent research has questioned these  
50 assumptions particularly for complex or unfamiliar goods and non-market goods. Subsequently,  
51 respondents may express lexicographic preferences, whereby they are unwilling to trade away any  
52 quantity of the good (Spash et al, 2009), and a number of biases which may obscure their true  
53 preferences. In particular when respondent awareness of the hypothetical nature of the study  
54 affects their response (hypothetical bias – e.g. Ivehammer, 2009) or where respondents avoid the  
55 risks of change even if they disapprove of the status quo (status quo bias – e.g. Boxall et al, 2009).

56 Stated preference surveys have been used to value a range of ecosystem services such as  
57 water quality (Zander and Stratton, 2010), recreation (Christie et al, 2007) and carbon sequestering  
58 (MacKerron et al, 2009). However, while final services, those with distinct end products that are  
59 directly consumed (Fischer et al, 2009), such as water quality, are more tangible and comprehensible  
60 to respondents who interact with them, intermediate services (those which enhance the production  
61 of end products), such as pollination, are often complex ecological concepts that the public find  
62 difficult to attribute value to. This can make valuations for ecosystem services difficult to elicit  
63 accurately with stated preference methods, due to the limited information available to respondents  
64 (Christie and Gibbons, 2011). This in turn increases the probability of respondents using decision  
65 simplifying strategies rather than fully considering all the information presented when expressing  
66 their preferences, further biasing the results (Meyerhoff and Liebe, 2009). Nonetheless, if carefully  
67 developed, stated preference studies can be used to capture aspects of ecosystem service benefits  
68 that are not included in existing valuation studies.

69 This study uses a choice experiment survey to assess respondents stated willingness to pay  
70 to conserve pollinators in order to prevent marginal losses in two previously unvalued final benefits  
71 of pollination services; the relative availability of UK grown produce and the diversity of aesthetic  
72 wildflowers. Presently, many key insect pollinated fruits are largely supplied by imports, while by  
73 contrast the UK is largely self-sufficient in wind-pollinated cereal crops (DEFRA, 2013). Consumer  
74 concerns regarding pollution, accountability and local economic impacts involved in food imports,  
75 have prompted a growing preference for locally produced foods (Chambers et al, 2007; Brown et al,  
76 2009). As such, even if produce can be substituted with imports, loss of UK pollination services will  
77 reduce the availability of this preferential characteristic. Insect pollinated wildflowers can provide  
78 significant welfare benefits through enhancing the aesthetic quality of landscapes (Soini and  
79 Aakkula, 2007), habitats (Lindemann-Matthies, 2010; Junge et al, 2011) and road verges (Akbar et al,  
80 2003). This aesthetic quality has substantial impacts on perceptions of landscapes (Natural England,  
81 2009) and socio-cultural values associated with connectivity with nature (Kellert, 1996).  
82 Subsequently, destabilisation of plant-pollinator networks and the consequent loss of flowering

83 species may diminish these benefits. Based upon this information, this study expects that  
84 respondent willingness to pay for pollinator conservation will rise in relation to the improving quality  
85 of these final goods.

## 86 **2. Methods**

### 87 *2.1. Experiment development and sampling*

88 This study evaluates respondent willingness to pay (WTP) to prevent losses in multiple  
89 pollination service end products using a choice experiment questionnaire. Choice experiment  
90 surveys present respondents with several bundles of goods and services with different attributes  
91 and ask them to indicate their preferred bundle. By attaching a cost to each choice and taking  
92 several choice sets per individual, choice experiments can be used to assess respondents' willingness  
93 to pay for marginal changes in each attribute rather than just the bundle as a whole.

#### 94 *2.1.1. Design*

95 Typically, attributes are derived from policy, prior preferences elicited or scientific  
96 predictions, however quantitative relationships between pollinator populations, pollination service  
97 levels and end production are difficult to extrapolate in an easily comprehensible manner. The  
98 attributes selected for this choice experiment were aesthetic wildflower diversity, the relative  
99 availability of UK produce and price. Attribute levels were specified identically as changes in current  
100 levels compared to now from no change to -30% in a linear incremental scale (Table 1) to elicit  
101 respondent willingness to pay to avoid losses in these pollination service benefits. These seemed  
102 sufficient to incentivise changes between options. The attributes were confirmed as suitable by a  
103 focus group, which considered the use of tax as payment vehicle (the hypothetical means by which  
104 payment would be collected) and the attribute levels to be comprehensible and believable. The cost  
105 attribute was framed as a possible future taxation to maintain realism (Ivehammar, 2009) and  
106 presented as both a monthly and annual increase. The cost attribute levels were modified after a 90  
107 household pilot survey, so as to increase the variation in choices as most pilot respondents picked  
108 only the most expensive options.

109 Values ascribed to these attributes do not directly represent a valuation of pollinators. For  
110 simplicity, bees were chosen as a focal species because of their widely recognised importance as  
111 pollinators (Klein et al, 2007) and recent UK media coverage of declining populations. A measure of  
112 bee populations was considered as an attribute in the initial design however focus group discussions  
113 indicated difficulty in placing values on percentage changes in bee populations in relation to other  
114 attributes, indicating instead that it was the secure existence of the taxa and the services that they  
115 provide that mattered. Furthermore, such a variable could complicate the scenario by creating  
116 choice sets where bees decline but their services remain, which although plausible, many  
117 participants found hard to comprehend. Alternatively, other ecosystem functions may compensate  
118 for lost pollination services (Bommarco et al, 2013) however this introduces complex, multiple  
119 ecosystem service concepts into the scenario. The presence of a "do nothing" status quo option,  
120 whereby there is no additional effort is made to preserve bees in the UK, instead allows for some  
121 estimate of the intrinsic value respondents attach to the continued existence of bees by statistically  
122 analysing the impact of "non status-quo" options on WTP.

123

124 **Table 1** Choice attribute levels

Attribute	Levels
1. UK grown fruit and vegetables available in local shops compared to now	-30%*, -20%, -10%, Same as now
2. Variety of wildflowers in local green spaces compared to now	-30%*, -20%, -10%, Same as now
3. Monthly tax increase to you	£0*, £0.5, £1, £1.5, £2, £2.5, £3, £3.5, £4

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\* = status quo attribute levels

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30 choice sets were initially developed with attribute balanced (i.e. attribute levels of each attribute appear across all choice sets the same number of times), D-optimal design algorithms, which aim to produce more statistically robust choice sets by minimising the standard error or standard deviations of the parameter estimates using initial assumptions about parameter signs and magnitudes. However, typical of D-optimal choice sets generated without adequate prior information, some of the resultant choice sets had little variation and often featured dominant options whereby one option was lower cost and offered higher benefits than the other, non-status quo option. Subsequently, choice sets were subjectively altered to eliminate dominant options and provide greater utility differences while maintaining attribute balance within the alternatives. Each respondent was presented with 6 choice sets, each with two unique alternatives to the status quo to reduce status quo bias by offering a range of alternatives (Rolfe and Bennett, 2009). The final questionnaire, designed following Dillman (2000), contained a cover letter providing respondents with information regarding pollination services provided by bees and the potential impacts of declines and outlined a scenario whereby taxation would be distributed by an apolitical government department to prevent and reverse declining bee populations in the UK.

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To reduce hypothetical bias and incentivise truthful response, the sample was informed that, while presently hypothetical, the changes could be implemented by 2015 with enough popular support and would be applied across the UK. An A4 picture sheet was included containing 4 pictures of the same flower meadow featuring approximately 10 plant species (flowering and non-flowering), with a single species in each removed in all but the first, providing a visual representation of declining floral diversity which may otherwise be difficult for respondents to form preferences for (Bateman et al, 2009). Visual representations of changing levels of UK fruit and vegetables were considered but judged impractical as response to crop deletion may be influenced by respondent food preferences. Final questionnaire content was checked with a focus group for clarity and simplicity of language and relevance of questions.

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### 2.1.2. Respondent attitudes and attributes

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To capture the effect of respondent attitudes, environmental ethical stance and exposure to the choice attributes, the questionnaire asked respondents a series of questions to evaluate their attitudes and exposure towards the choice attributes, bee conservation and general concern, their ethical stance regarding conserving biodiversity, based upon an environmental-anthropogenic scale (Spash et al 2009) and whether they agreed or disagreed with funding bee conservation through taxes to better identify protest responses (Meyerhoff and Liebe, 2009). A final section contained a

160 series of questions regarding respondent demographics, brackets of which were taken from the  
161 national census.

### 162 2.1.3. Sampling

163 Positive attitudes and willingness to pay for environmental goods/services are often  
164 increased by greater exposure and personal relevance of the service (Meyerhoff and Liebe, 2009)  
165 and decreased with further distance from the good/service (Bateman et al, 2006). Consequently,  
166 sampling was conducted over 3 counties in England; Kent, Lincolnshire and North Yorkshire based on  
167 the prominence of horticulture relative to arable crops reported in DEFRA (2013) to capture any bias  
168 caused by the significance insect pollinated crops to local agriculture.

169 To maximise the breadth of potential respondents given the budget available to the project,  
170 the questionnaire was designed as a postal based survey, allowing for more questions to be posed  
171 than phone or interview surveys can be answered at respondent discretion and can be more widely  
172 distributed (Bateman et al, 2002). By contrast, postal surveys innately suffer from self-selection bias  
173 towards retired and unemployed respondents (Dillman, 2000) and often have low response rates;  
174 necessitating large samples. In order to ensure an acceptable number of responses, a total of 2300  
175 questionnaires were mailed to a purchased sample of English households, weighted by the number  
176 of households within each 4 digit postcode area in order to increase sample representativeness.  
177 Budget limitations prevented the sending of reminders which may have increased the response rate.

## 178 2.2. Analysis

### 179 2.2.1. Choice analysis and Willingness to Pay

180 Responses were analysed using a hierarchical Bayes Logit model which uses Bayesian  
181 processes to assess the probability of a respondent selecting a particular option based on the  
182 attributes of options they have been observed to make. Estimates of parameters are made with  
183 respect to the individual and for the mean and variance of the population as a whole; if price is  
184 included in the choices then the maximum price the bundle will be selected over all other bundles is  
185 the maximum WTP for the bundle. Utility, the quantitative benefit to personal wellbeing that a  
186 respondent receives from a bundle, is specified as:

$$187 \quad U_{ni} = V_{ni} + \varepsilon_{ni} \quad (1)$$

188 Where  $U_{ni}$  represents the utility of respondent  $n$  from choosing bundle  $i$ ,  $V_{ni}$  represents deterministic  
189 utility, a vector of observed characteristics regarding the attributes of  $n$  and  $i$  and  $\varepsilon_{ni}$  represents  
190 error, a vector of unobserved characteristics and stochastic variation in respondents which is  
191 assumed to have a Gumbell distribution. Respondents are assumed to maximise utility so that the  
192 choice probability ( $P$ ) of  $n$  selecting  $i$ , is:

$$193 \quad P_{ni} = P(U_{ni} > U_{nj} \forall j \neq i) \quad (2)$$

194 In standard Mixed Logit, an individual's choice probability can therefore be estimated, based on  
195 observed characteristics. The deterministic component of utility is modelled as;

$$196 \quad V_{ni} = \beta_n' x_{ni} \quad (3)$$

197 where  $\beta_n$  is a normally distributed vector of parameters for individual n with mean  $\alpha$  and covariance  
 198 matrix  $\omega$

$$\beta_n \sim N(\alpha, \omega) \quad (4)$$

199  
 200  $x_{ni}$  represent the attributes levels of bundle i presented to respondent n. Subsequently, the  
 201 probability that respondent n chooses bundle i becomes:

$$P_{ni} = \left( \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \right) \quad (5)$$

202

203 Where  $x_{ni}$  are attributes within  $V_{ni}$ . The marginal utilities for each attribute are the elements of  $\beta_n'$   
 204 within the standard Mixed Logit. Typically normal or log-normal (where the sign of the parameter is  
 205 known) and can be specified differently for each element of  $\beta_n'$ .

206 The model utilised in this study estimates  $\beta_n'$  using 500,000 Monte-Carlo Markov Chain  
 207 (MCMC) draws, retaining every 50<sup>th</sup> draw to compile into  $\beta_n'$  in order to decrease the co-dependence  
 208 of the sampled values. As estimates of  $\beta_n'$  should be independent of starting points for the MCMC  
 209 estimation, an additional 50,000 draws were taken and discarded prior to the main draws. Model  
 210 priors for  $\alpha$  and  $\omega$  were estimated using relatively diffuse normal priors for  $\alpha$  and Wishart prior  $\omega$  as  
 211 specified in Train (2003 -Chap. 12). Analysis was undertaken in both preference space, where the  
 212 distribution of marginal utility is estimated and the rate of marginal utility substitution between  
 213 attributes calculated on this basis, and WTP space, which estimates the rate of marginal utility  
 214 substitution directly and may produce greater stability in WTP estimates (Balcombe et al, 2009).  
 215 Preliminary analysis of the data indicated that model fit was best when evaluated in preference  
 216 space rather than WTP space. As preference space estimates can be prone to bias from extreme  
 217 values, median attribute coefficients and WTP estimates were used in place of mean estimates.

218 Respondent descriptors were incorporated into the model on the basis of research interest  
 219 and a priori expectation regarding their significance. Age and income categories and attitudes  
 220 towards taxation were included as continuous variables. Dummy variables were used to account for  
 221 income refusal and the 3 counties with North Yorkshire used as a reference. The influence of the  
 222 level of urbanisation respondents encountered was assessed on a 1 (urban) to 3 (rural) gradient with  
 223 those indicating "other" occupancy placed in category 2. Other demographic and attitudinal  
 224 variables were evaluated separately to avoid over-parameterisation (see Appendix 1).

### 225 2.2.2. Attribute non-attendance

226 Attribute non-attendance (ANA), whereby respondents ignore one or several attributes of a  
 227 choice in making their decisions, is often handled by setting the marginal utility of the attribute to  
 228 zero for non-attendant respondents (e.g. Balcombe et al. 2011) or removing the respondent entirely  
 229 in the case of non-attendance on the cost attribute (e.g. Zander and Stratton, 2010). These  
 230 approaches assume that respondents either have no utility, and thus zero WTP, attached to ignored  
 231 attributes or are misreporting their preferences (Hensher, 2006). In actuality, respondent decisions  
 232 may be dominated by the other attributes or their preferences towards an attribute may be simply  
 233 polarised towards or against extreme values. Alternatively, it can be assumed that non-attendant  
 234 respondents have a lower marginal utility value for the attribute than attendees. This can be  
 235 modelled by incorporating a shrinkage parameter which is assumed to lie on a normally distributed  
 236 0-1 scale. Consequently if a respondent is non-attendant on an attribute (k) their marginal utility for



237 that attribute becomes:  $\beta_{nk}^* = shrinkage \times \beta_{nk}$ . Initial work suggests that this ANA shrinkage  
238 approach outperforms other methods of treating ANA (Kehlbacher et al, 2013). The approach used  
239 here posits a distribution for the marginal utilities dependant on non-attendance data, making no  
240 stronger assumptions about the nature of independence than a latent variable approach.

### 241 2.2.3. Extrapolation

242 As postal surveys tend to have low response rates and are vulnerable to self-selection  
243 biases, whereby only those interested in the questionnaire respond, extrapolating WTP estimates to  
244 the total UK working population may overestimate total value. As such, two extrapolations were  
245 conducted for each model, one assuming that all 28.2m working adults aged 18-64 in the UK (ONS,  
246 2011) would be willing to pay (Upper Bound) while another assumes that the percentage of the  
247 sample that did not respond had no WTP for pollination service conservation (Lower Bound).

### 248 2.3.4. Estimating the value of pollination services

249 Typically, the value of pollination services to crops is estimated using a basic production  
250 function, by multiplying each crops insect pollinator dependence ratio by the total market price of  
251 the crop (see e.g. Gallai et al, 2009). This study uses a similar methodology to estimate the value of  
252 pollination services to the non-market benefits in the questionnaire; estimating the proportion of  
253 each benefit that arises from pollination services.

254 For UK produce (fruits and vegetables), this was based on the proportion of UK domestic  
255 crop consumption that would be lost without pollination services. The total volume of UK production  
256 in 2010 for the domestic market was derived from DEFRA (2013,2012). As only crop produce  
257 produced and sold in the UK was valued, the production of each crop was multiplied by 1 - the % of  
258 crop exported. Where specific crop data was not available, crop groups (fruit or vegetables) was  
259 used as a proxy. The proportion of domestic production lost was estimated by multiplying the  
260 volume of production by their insect pollination dependence ratios from Smith et al (2011) and  
261 Gallai et al (2009), resulting in an estimate of as ~12% of domestic consumption arising from  
262 pollination services. Assuming a linear relationship between pollinator abundance and services  
263 (Garibaldi et al, 2013), this means that a 1% decline in insect pollinator populations would produce a  
264 0.12% decline in the availability of UK fruit and vegetables.

265 Ollerton et al (2011) estimate that ~78% of temperate flowering plants are pollinated by  
266 insects, however it is not yet known what proportion of these depend exclusively upon insect  
267 pollination (or specifically pollination by bees), or if this reflects the pollinator dependence of UK  
268 flora. Nonetheless, if it is assumed that this ratio is correct and that at least half of these species are  
269 entirely dependent on insect pollination this means that a 100% loss of insect pollinators would  
270 produce a 39% decline in wildflower diversity. The loss of 1% of insect pollinators would therefore  
271 be expected to produce a 0.39% decline in wild plant diversity, assuming again a linear relationship  
272 between pollinator abundance and services.

## 273 3. Results

### 274 3.1. Response

275 In total 312 questionnaires (14%) were returned, of which 278 were completed sufficiently  
276 to be included in analyses, resulting in 1668 choice observations. Those respondents that did not

277 complete a choice set were assumed to have answered “don’t know”. The response rate was  
278 approximately equal across counties. Typical of postal questionnaires, a high proportion of  
279 respondents were in the higher age brackets with 76.3% of respondents being aged 45 or over and  
280 only 7.2% under 30. Most respondents currently live in market or commuter towns (44%) and rural  
281 areas (33%) with only 15% of respondents residing in urban areas although the proportion of  
282 respondents growing up in each category was approximately equal. Respondent income was largely  
283 in the lower income categories although ~11% indicated annual income of >£75k. Approximately  
284 15% of respondents stated that they were non-attendant on either UK produce or wildflower  
285 diversity while 46% were non-attendant on taxation.

286 Respondent awareness of UK bee declines was very high (88%). More than half of  
287 respondents (68%) indicated that they grew their own fruit and vegetables and 22% were members  
288 of a relevant Non-Government Organisation. Only 1% kept bees and 8% had work experience in a  
289 relevant field. Attitudes towards bee conservation were positive with 97% agreeing with the  
290 statement that bee conservation was important and <1% disagreeing. Approximately 75% agreed  
291 with the statement that environmental protection would require funding through taxation versus 9%  
292 disagreeing. Attitudes towards the attributes were also generally strong and positive, although only  
293 18% regularly visit green spaces. Respondent ethical stances were more mixed with ~70% of  
294 respondents indicating equitable (humans and other species have equal rights) or anthropocentric  
295 (humans have more rights than other species) attitudes.

296 Pearson’s Correlation analysis indicates highly significant relations between several  
297 respondent attitude and demographic parameters (Appendix 2). In particular, general environmental  
298 concern correlates very strongly with positive attitudes towards the attributes and bee conservation,  
299 acceptance of taxation as a means of funding environmental protection and environmentalist ethical  
300 stances. Acceptance of environmental taxation positively correlated with respondent qualification  
301 and income. Attitudes towards bee conservation correlated positively with respondent age and  
302 negatively with number of dependants.

### 303 *3.2. Choice Probability Parameters and Willingness to Pay*

304 In both the attribute non-attendance (ANA) shrinkage (Model 1) and Cost Attendees only  
305 (Model 2) models, all choice attributes had the expected signs for both preferences and WTP  
306 estimates (Table 2) (£175.88/respondent/year vs £95.83/respondent/year) with attribute specific  
307 WTP approximately twice that of Model 1. As the questionnaire offered bundles with varying  
308 degrees of loss of attributes, all attributes entered the model as negative values, including cost -  
309 reflecting its nature as a negative impact upon respondent utility. In Model 1 ANA shrinkage was  
310 estimated at 0.44 (s.d. 0.07), indicating that attenders derived approximately twice as much utility  
311 from these attributes as non-attenders. In both models, the alternative specific constant (ASC)  
312 parameter, representing willingness to pay to avoid the status quo situation, was negative and  
313 produced high WTP values indicating that respondents strongly rejected the “do nothing” status  
314 quo. There was little difference in WTP for a 1% increase between UK produce or wildflower  
315 diversity in either model, suggesting that respondents were largely concerned with avoiding the  
316 status quo.

317

318 **Table 2** Model coefficients and WTP for choice attributes (standard deviations in brackets)

Attribute	Model 1		Model 2	
	Choice Probability	WTP	Choice Probability	WTP
ASC	-1.04* (1.16)	-£73.4 (5692.1)	-1.195* (1.44)	-£46.3 (7861)
UKP	0.2757* (0.29)	£1.79 (1066.9)	0.2361 (0.31)	£0.81 (1514.8)
WDF	0.2335* (0.34)	£1.63 (1047.9)	0.1751* (0.38)	£0.84 (1182.4)
CST	0.9512* (1.53)		1.2856 (2.51)	
Total WTP/Respondent <sup>1</sup>		£175.88		£95.83
ANA Shrinkage Parameter		0.44		
Maximum Simulated Log-Likelihood		-811.21		-515.19
Pesudo R <sup>2</sup>		0.72		0.49
Number of Respondents		278		151

319 Key: ASC = Alternative specific constant; UKP = UK produce availability retained (in %); WDF = Wildflower diversity retained  
 320 (in %); CST = Cost in £/year; Total WTP/respondent = WTP for an alternative that results in a 0% change of UKP and WDF. \*  
 321 = significant at the 5% level. \* = significant effect based on Pseudo t-values approaching 2, ANA Shrinkage = the attribute  
 322 non-attendance shrinkage parameter. Pseudo R<sup>2</sup> = The McFadden's Pseudo R2 value.

323

324 Against expectations, most respondent descriptors proved non-significant<sup>4</sup> upon selecting  
 325 non status-quo alternatives, particularly in Model 2 (Table 3). As expected, respondents that  
 326 disagreed with paying for taxes to provide environmental protection were significantly more likely to  
 327 accept the status quo in both models. In Model 1 these respondents were significantly less likely to  
 328 accept options which produced greater levels of wildflowers and UK produce but not less likely to  
 329 select options which had a greater cost. By contrast, in Model 2, strong tax avoidance attitudes only  
 330 significantly reduce the probability of respondents selecting higher cost options. In both models,  
 331 respondents from Lincolnshire were significantly more likely to select higher cost options, regardless  
 332 of other attributes, indicating a greater WTP for bee conservation. In common with past research  
 333 (e.g. Broberg and Brännlund, 2009), Model 2 demonstrates differences between urban and rural  
 334 respondents with rural respondents holding lower WTP than urban residents. Finally, in Model 1,  
 335 higher respondent income marginally increased the likelihood of selecting options with greater  
 336 availability of UK produce.

337

<sup>4</sup> The term significant is used here to signify that the standard deviations were more than twice that of the means as Bayesian analysis does not technically allow for tests of significance.

338 **Table 3** Extrapolated upper bound and lower bound population total WTP values

	Upper Bound		Lower Bound	
	Model A	Model B	Model A	Model B
All Attributes	£4.96bn	£2.70bn	£695M	£379M
ASC	£2.07bn	£1.30bn	£290M	£183M
UKP	£1.5bn	£685M	£212M	£96M
WDF	£1.3bn	£711M	£193M	£100M

339 Key: ASC = Alternative specific constant; UKP = UK produce availability retained (in %); WDF = Wildflower diversity retained  
 340 (in %); CST = Cost in £/year. Total population = WTP values extrapolated to all 28.2m UK working adults aged 18-64.  
 341 Response Rate = WTP values are extrapolated to 3.9m members (14%) of the working population, reflecting the response  
 342 rate of the questionnaire itself. Model A considers ANA using an ANA shrinkage method. Model B considers ANA by  
 343 removing non-attenders from the sample.  
 344

345 Upper bound extrapolations of the WTP values, which assume all 28.2M working adults in  
 346 the UK would be willing to pay the values reported in table 2, result in an extremely high total value  
 347 of £4.96bn and £2.70bn for Models 1 and 2 respectively (Table 4). However, this value is likely to be  
 348 exaggerated by stronger response rate from those willing to pay than those who are not, a lower  
 349 bound analysis was conducted which assumes that a proportion of UK working adults equal to the  
 350 response rate (14% - 3.94M adults) are willing to pay these values. This resulted in much more  
 351 conservative extrapolations of £695M - £379M for Models 1 and 2 respectively; equivalent to an  
 352 annual tax increase of £24.6 and £13.4 per UK taxpayer.

353 **Table 4** Coefficients for mean effects for respondent descriptors (standard deviation in brackets)

	Model 1				Model 2			
	ASC	UK Produce	Flowers	Tax	ASC	UK Produce	Flowers	Tax
$\alpha$	-1.40*	0.27*	0.51*	2.6*	-3.24*	0.26	0.50*	2.88
	(0.58)	(0.13)	(0.15)	(1.46)	(1.66)	(0.2)	(0.24)	(2.04)
Age	0.01	0.02	0.01	-0.09	-0.15	0.02	0.02	-0.08
	(0.08)	(0.02)	(0.02)	(0.23)	(0.24)	(0.03)	(0.03)	(0.3)
Income	0.01	0.03*	0.00	0.23	0.08	0.01	-0.01	0.07
	(0.07)	(0.02)	(0.02)	(0.2)	(0.19)	(0.03)	(0.03)	(0.26)
Income Refused	0.22	0.02	-0.09	-0.73	0.98	-0.04	-0.16	-1.24
	(0.29)	(0.08)	(0.09)	(0.77)	(0.84)	(0.12)	(0.14)	(0.99)
Kent	-0.26	-0.03	-0.07	-1.05	-0.67	-0.04	-0.08	-1.35
	(0.22)	(0.06)	(0.07)	(0.64)	(0.69)	(0.11)	(0.12)	(1.09)
Lincolnshire	-0.18	-0.01	-0.13	-1.87*	-0.32	-0.08	-0.16	-2.74*
	(0.27)	(0.07)	(0.08)	(0.82)	(0.8)	(0.12)	(0.15)	(1.32)
Urban/Rural	-0.10	0.02	-0.01	-0.52	-0.09	0.002	-0.06	-0.97*
	(0.13)	(0.03)	(0.04)	(0.39)	(0.38)	(0.06)	(0.06)	(0.52)
Tax Attitudes	0.36*	-0.07*	-0.10*	0.39	0.9*	-0.03	-0.05	0.94*
	(0.13)	(0.03)	(0.03)	(0.33)	(0.42)	(0.05)	(0.05)	(0.44)

354 Key  $\alpha$  = constant/intercept. Age = Age category as per the 2001 UK census. Income = Income categories as per the 2001 UK  
 355 census. Income refused = dummy variable where 1 indicates a refusal to state income. Kent = Dummy variable denoting  
 356 respondent from Kent. Lincolnshire = Dummy variable denoting respondent from Lincolnshire. Urban/Rural = continuous  
 357 variable indicating urban or rural dwelling. Tax Attitudes = continuous variable indicating increasing aversion to tax. \* =  
 358 significant effect based on Pseudo t-values approaching 2

359 The marginal value of pollination services to these end benefits was estimated by  
 360 multiplying the WTP for each attribute by the proportion of the attribute that can be attributed to  
 361 pollination services (12% and 39% respectively) (Table 5). Multiplying the values per 1% of service by  
 362 30, representing the maintenance of all services under risk in the scenario presented, results in a

363 total WTP to fully maintain these end benefits of £25.5/person under model 1 and £12.6/person  
 364 under model 2. Extrapolated using the upper and lower bound estimation, this indicated pollination  
 365 services have a value of between £50M to £720M to these non-market benefits.

366 **Table 5** Estimated WTP values for pollination services

		Model 1	Model 2
Willingness to Pay to maintain 1% of the attribute	UK Produce	£1.79	£0.81
	Wildflower Diversity	£1.63	£0.84
% change from a 1% loss of pollinators	UK Produce	0.12	0.12
	Wildflower Diversity	0.39	0.39
Estimated WTP for a 1% maintenance of pollination service	UK Produce	£0.21	£0.10
	Wildflower Diversity	£0.64	£0.33
Estimated WTP to maintain 100% of services	UK Produce	£21.48	£9.72
	Wildflower Diversity	£63.57	£32.76
Estimated Total WTP	Upper Bound	£720M	£350M
	Lower Bound	£101M	£50M

367 Key: Upper Bound = the sum of WTP to maintain 100% of pollination services extrapolated to the entire tax paying  
 368 population of the UK. Lower Bound = the sum of WTP to maintain 100% of pollination services extrapolated to 14% of the  
 369 tax paying population of the UK. Model 1 = Analysis including Attribute non-attendance shrinkage Model 2 = analysis made  
 370 by removing respondents that did not attend cost.

371 **4. Discussion**

372 *4.1. Model Outputs*

373 This study has demonstrated that respondents possess a high willingness to pay for avoiding  
 374 the loss of the non-market end benefits of pollination services. However the results are likely to be  
 375 upwardly influenced by a number of biases and respondent factors, potentially exaggerating final  
 376 estimates. Especially strong status quo aversion was prevalent throughout the responsive  
 377 population, producing very high Willingness to Pay (WTP) values for the alternative specific constant  
 378 (the willingness to pay to avoid the status quo) in both the models estimated. This may be the  
 379 product of high existence values, (the innate utility respondents attach to knowing that a good or  
 380 service exists) for both bees and the end products of pollination services used as attributes. This is  
 381 supported by the strong similarities between the alternative specific constant determined using  
 382 attribute non-attendance shrinkage and the findings of Mwebaze et al (2010) which estimate a total  
 383 WTP for bee conservation alone of £71.24/respondent. This study made some reference towards the  
 384 benefits of pollination services but did not describe them in detail. As such the values reported in  
 385 this study may represent value added to this existence value due to more explicit information on the  
 386 benefits of pollination services. Alternatively, the findings could be interpreted as a disambiguation  
 387 of the WTP reported by Mwebaze et al (2010) with some, moderate increase in WTP due to differing  
 388 information. Respondent's highly positive attitudes towards bees and the products of pollination  
 389 further substantiate this notion. Another possibility is that respondents may have held an anti-status  
 390 quo bias - completely rejecting the status quo situation of pollinator losses. This may reflect  
 391 lexicographic preferences against the status quo, where respondents found the do nothing scenario  
 392 totally unacceptable. Alternatively the costs of action may not have disincentivised payments  
 393 enough to favour the no-cost status quo, especially as no other benefits of accepting the status quo  
 394 were presented (e.g. Hynes et al, 2010). This is supported by the lack of significant income effects  
 395 upon either the alternative specific constant or the tax attribute in response probability.

396 Although the high proportion of respondents were of retired age (>60years) may cause an  
397 upward bias in WTP as these respondents would not have to pay any tax imposed, no significant  
398 effect of age category was found for either alternative specific constant or the cost attribute.  
399 Hypothetical bias, where respondents exaggerate their willingness to pay because of the  
400 hypothetical nature of the questionnaire, may also explain the low significance of the cost attributes  
401 on respondent choices, high tax non-attendance among respondents and the number of  
402 respondents who indicated objections to taxation still expressed preferences for conservation  
403 options. Future research in this area may benefit from the introduction of cheap talk devices in  
404 choice experiment scenario (Carlsson et al, 2005), which explicitly explain some or all of the survey  
405 mechanics that may cause bias, such as overstating preferences, to deepen respondents  
406 consideration of actual preferences (but see Henscher, 2010).

407 Of the two approaches to handling attribute non-attendance; using a shrinkage factor  
408 (Model 1) was found to produce significantly greater WTP estimates than removing respondents  
409 that expressed non-attendance for costs (Model 2 - Table2). This arises because Model 1 indicates  
410 that cost had approximately half the effect on utility of non-attenders compared to attenders,  
411 resulting in non-attenders maintaining a substantial influence on WTP estimates. Under both  
412 models, respondent WTP for each of the insect pollinated benefit attributes was very similar. This  
413 may result from similar levels of exposure to these attributes, resulting in stronger (Christie and  
414 Gibbons, 2011), more stable preferences (Bateman et al, 2008). Another possible means of  
415 controlling for the effects of attribute non-attendance is the use of Bayesian stochastic attribute  
416 selection (Scarpa et al, 2009), or by asking respondents whether they were non-attendant in each  
417 choice set (Scarpa et al, 2010). These methodologies however are limited by their respective  
418 applicability of Latent class models and increased question complexity respectively. These findings  
419 highlight the importance of considering attribute non-attendance in choice modelling, particularly if  
420 the findings are to be extrapolated beyond the sample population.

421 The findings of this study also raise questions regarding the extrapolation of choice  
422 experiment results towards total populations. National WTP values ranging from £4.96bn-£695M  
423 and from £2.7bn-£379M under Models 1 and 2 respectively based on the extrapolation method  
424 involved. Contrarily, this lower bound estimate assumes that non-respondents have no WTP where  
425 they may in fact simply be unwilling or unable to respond, particularly as reminders were not sent to  
426 prompt further response. Typically national scale extrapolations of stated preference value have  
427 assumed that non-respondents hold similar WTP values to respondents. However the lower bound  
428 estimates in this study, whereby the values were only assumed to apply to a percentage of the  
429 population equal to the response rate, illustrate not only the disparity in estimates, particularly  
430 where WTP is high, but the resultant tax increase required. A deeper examination of the means to  
431 extrapolate WTP from stated preference studies could make such studies more applicable to policy.  
432 Ideally, this should be accompanied with further analysis of the trade-offs in welfare for those  
433 unwilling to pay for the new policy.

#### 434 *4.2. Valuing Pollination Services*

435 Most critically, the results provide a basic first indication of the value of pollination services  
436 to final goods and services beyond crop production. The values estimated (£25.5-£12.6/person)  
437 strongly hinge on the assumption that pollination responds linearly to pollinator abundance within  
438 the landscape. Although this has been broadly demonstrated for insect pollinated crops (Garibaldi et  
439 al, 2013) the shape of this relationship within wild plant networks is presently unknown and it is

440 likely to plateau after a certain level of pollen deposition. Furthermore it does not include the  
441 potential additive or multiplicative effects of pollinator diversity (e.g. Greenleaf and Kremen, 2006).  
442 However these estimates remain useful as an initial valuation of the value of pollination services to  
443 non-market public benefits which have been hereto overlooked by valuation studies. The high value  
444 placed on the diversity of aesthetic wildflowers in particular highlights the potential value of  
445 pollination services outside of crop production. Furthermore, they do not capture the value added to  
446 consumers outside of the landscape that benefit from the availability of preferred nationally sourced  
447 produce.

#### 448 *4.3. Implications*

449 Strong respondent concern about the pollinator declines and high WTP both for the end  
450 benefits of pollination services and the avoidance of the status quo suggest there may be scope for  
451 enhancing public participation in pollinator conservation, beyond perhaps, that of monetary  
452 contribution. For instance voluntary monitoring and recording schemes, have yielded substantial  
453 information on urban bumblebee nesting (Osborne et al, 2008), distribution (Kadoya et al, 2009) and  
454 population dynamics (Kawk, 1997). At a larger scale such public participation in wildlife monitoring  
455 schemes can also provide significant primary data for use in future research (e.g. Carvalheiro et al,  
456 2013). Although further research will be required to translate the preferences recorded within this  
457 study into measures of public willingness to participate in such efforts, the findings nonetheless  
458 provide compelling evidence that the public are likely to be supportive of efforts and public spending  
459 on pollinator conservation.

460 Most significantly, the findings highlight the importance of considering other benefits from  
461 pollination services beyond crops. However, the capacity of this study to accurately elicit these  
462 values is limited both by the extent of the survey and by a number of economic and ecological  
463 knowledge gaps. Although quantities of produce available for home production are broadly known,  
464 an unknown proportion of this will be used in processing rather than sold fresh. Consequently it is  
465 not possible to accurately estimate the proportion of UK produce for domestic consumption. This  
466 can be improved upon with a more detailed analysis of supply chains of insect pollinated produce  
467 within the UK, facilitating broader economic understanding of the vulnerability of UK consumers to  
468 losing domestic supplies. The relative importance of produce origin compared to price or quality also  
469 remains unquantified. As such, it is not possible to assess the impacts of other trade-offs that may  
470 result from a loss of pollination services; if consumer welfare increases more from a lower price than  
471 consuming local produce then lower cost imports may increase welfare overall. While recent studies  
472 have begun to draw generalised trends in the impacts of pollinator communities on service provision  
473 (e.g. Garibaldi et al, 2013) the relationships between pollinator abundance and diversity has not  
474 been similarly generalised. Furthermore, despite extensive assessment of the flora of the UK, to date  
475 there has not been an assessment of how many UK plant species benefit from pollination services to  
476 varying extents (unlike crops – Klein et al, 2007). Subsequently it is not possible to accurately  
477 determine how wild plant communities will react to a loss of pollinators despite evidence of parallel  
478 declines between pollinators and wild plants within the UK (Carvalheiro et al, 2013). Similarly, it is  
479 not know to what extent members of the UK public value different aspects of floral diversity within a  
480 viable landscape; for instance people may have a preference for orderly arrangements of flowers or  
481 a range of visually distinct species (Lindemann-Matthies et al, 2010). Understanding this would allow  
482 for a more accurate assessment of the aesthetic value of floral diversity and the subsequent  
483 contribution that pollination does or can make to it.

484 **5. Conclusions**

485 The findings of this study demonstrate that respondents have a very strong preference for  
486 situations that avoid the status quo scenario of pollinator and pollination service losses and are  
487 prepared to pay for these accordingly. These preferences are equally strong between the two  
488 benefits of pollination services, wildflower diversity and availability of UK produce, presented to  
489 respondents and were perhaps surprisingly not strongly influenced by respondent age, income or  
490 ethical stance. Although respondents who protested against tax were less likely to accept an  
491 alternative scenario they were nonetheless in favour of preserving pollination services and nearly all  
492 respondents felt that preserving pollinator populations was an important issue. With many drivers of  
493 pollination service decline set to continue, further research into public preferences for pollinator  
494 conservation will likely yield beneficial insights into both raising public support for pollinator  
495 conservation and the quantitative impacts of pollination services upon human welfare. A stronger  
496 understanding of public preferences for attributes of the produce they consume and the landscapes  
497 they view will enhance the accuracy and interpretation of these findings.

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