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Abstract: Objectives. Without urgent action, climate change will put the health of future populations at risk. Policies to reduce these risks require support from today's populations; however, there are few studies assessing public support for such policies. Willingness to pay (WtP), a measure of the maximum a person is prepared to pay for a defined benefit, is widely used to assess public support for policies. We used WtP to investigate whether there is public support to reduce future health risks from climate change and if individual and contextual factors affect WtP, including perceptions of the seriousness of the impacts of climate change.

Study design. A cross-sectional British survey.

Methods. Questions about people's WtP for policies to reduce future climate change-related deaths and their perceptions of the seriousness of climate change impacts were included in a British survey of adults aged 16 and over (n=1859). We used contingent valuation, a survey-based method for eliciting WtP for outcomes like health which do not have a direct market value.

Results. The majority (61%) were willing to pay to reduce future increases in climate change-related deaths in Britain. Those regarding climate change impacts as not at all serious were less willing to pay than those regarded the impacts as extremely serious (OR 0.04, 95% CI 0.02-0.09). Income was also related to WtP; the highest-income group were twice as likely to be willing to pay as the lowest-income group (OR 2.14, 95% CI 1.40-3.29).

Conclusions. There was public support for policies to address future health impacts of climate change; the level of support varied with people's perceptions of the seriousness of these impacts and their financial circumstances. Our study adds to evidence that health, including the health of future populations, is an outcome that people

value and suggests that framing climate change around such values may help to accelerate action.

Research Data Related to this Submission

There are no linked research data sets for this submission. The following reason is given:

ONS Opinions and Lifestyle data, including commissioned modules, are held on the UK data service archive and can be accessed from the archive

<https://www.ukdataservice.ac.uk/get-data.aspx>

Willingness to pay for policies to reduce future deaths from climate change: evidence from a British survey

Box 1: willingness-to-pay question

Each participant was presented with a variation of the following question, in which text in square brackets was varied:

Climate change is expected to have a negative impact on health and wellbeing and scientists expect that climate change will cause more deaths in the UK. Scientists from the UK Committee on Climate Change predict that if we continue to use energy in the way we currently do, there may be:

- 7000 more deaths per year in the UK by 2050 (over 3 times higher than current levels) and
- 12,000 more deaths per year in the UK by [A] (6 times higher than current levels).

[B] are two groups that are particularly at risk. It will cost money to put in place environmental policies to reduce these risks. We would like to know what you feel would be an acceptable amount of public spending to reduce these impacts.

Would you be willing to pay an additional [X] in your taxes each month for the NEXT TEN YEARS to reduce climate-related deaths to current levels?

The varied texts were randomly assigned so that:

- A quarter of respondents were presented with A = "2080" & B = "The elderly and the very young" (of these, one fifth received each of the five bid amounts X: £1, £2, £5, £10, £20)
- A quarter of respondents were presented with A = "2080" & B = "The elderly" (of these, one fifth received each of the five bid amounts X: £1, £2, £5, £10, £20)
- Half of respondents were presented with A = "2115" & B = "The elderly and the very young" (of these, one fifth received each of the five bid amounts X: £1, £2, £5, £10, £20)

Table 1: Perceived seriousness of the impacts of climate change

Demographic grouping	Per cent of respondents that consider the impacts of climate change:					% considering impacts extremely or fairly serious	% considering impacts not very or not at all serious	Number of participants
	Extremely serious	Fairly serious	Not very serious	Not at all Serious	Don't know/ refused			
All	41	45	9	3	2	86	12	1859
Gender								
Male	40	42	11	5	1	82	16	815
Female	41	48	7	2	3	89	8	1044
Generation								
Pre-1946	31	50	12	4	4	80	16	341
1946–1965	43	41	9	5	3	83	14	630
1966–1985	44	45	7	2	2	89	9	613
Post-1985	41	51	5	2	1	92	7	275
Income band								
Under £7280	44	45	6	2	2	90	9	326

£7280–£12479	37	44	12	3	4	81	15	368
£12480– £18719	38	47	9	4	2	84	14	332
£18720– £28599	43	47	5	3	2	91	8	330
£28600 and above	45	42	9	2	2	87	11	367
Don't know/refused	29	49	10	7	6	78	16	136
Level of education								
Degree or above	52	39	5	2	1	92	7	464
Below degree	37	47	9	3	3	84	13	1004
None	35	48	10	4	3	83	14	391

Table 2 Willingness to pay to reduce climate change-related deaths

Amount asked, £	Per cent willing to pay	Per cent not willing to pay	Per cent don't know/refused	Number of participants
1	78	20	2	344
2	70	27	3	381
5	60	38	2	407
10	51	45	4	368
20	46	51	3	359
All amounts	61	36	3	1859

Table 3 Mean and median willingness to pay per person (results from univariate logistic regression)

	Main model – data as received with missing responses to WtP question	Sensitivity analysis – all missing assumed to be unwilling to pay
Mean amount willing to pay (£)	19·17 (95%CI 15·64 – £22·70)	18·61 (95%CI 15·16 – £22·06)
Median amount willing to pay (£)	14·16 (95%CI £11·84 – £16·47)	13·13 (95%CI £10·96 – £15·29)

Table 4 Contingent valuation model and sensitivity analysis of likelihood of being willing to reduce heat-related deaths (results from multivariate logistic regression)

	Main model – data as received with missing responses to WtP question				Sensitivity analysis – all missing assumed to be unwilling to pay			
	Odds ratio	95% CI		P-value	Odds ratio	95% CI		P-value
Bid amount (per £10)	0.47	0.40	0.56	< 0.01	0.49	0.41	0.58	< 0.01
<i><u>Perceived seriousness of effects of climate change</u></i>								
Extremely serious	1				1			
Fairly serious	0.35	0.27	0.46	< 0.01	0.36	0.28	0.48	< 0.01
Not very serious	0.08	0.05	0.13	< 0.01	0.09	0.05	0.14	< 0.01
Not at all serious	0.04	0.02	0.09	< 0.01	0.05	0.02	0.11	< 0.01
<i><u>Generation</u></i>								
Pre-1946	1.08	0.76	1.53	0.66	1.09	0.78	1.53	0.61
1946–1965	1				1			
1966–1985	1.32	0.98	1.80	0.07	1.32	0.98	1.78	0.07
Post-1985	1.38	0.93	2.06	0.11	1.38	0.94	2.02	0.10
<i><u>Income band</u></i>								
Under £7280	1				1			
£7280-£12479	1.15	0.78	1.68	0.48	1.20	0.83	1.73	0.33
£12480-£18719	1.72	1.14	2.59	0.01	1.65	1.11	2.45	0.01
£18720-£28599	1.24	0.83	1.85	0.29	1.37	0.92	2.02	0.12
£28600 and above	2.14	1.40	3.29	< 0.01	2.18	1.44	3.32	< 0.01
<i><u>Level of education</u></i>								
Degree or above	1.37	1.00	1.88	0.05	1.33	0.98	1.81	0.07
Below degree	1				1			
None	0.80	0.58	1.12	0.20	0.79	0.57	1.08	0.14

Appendix: Missing data and multiple imputation approach

There were missing data for income band and perceived seriousness of the effects of climate change. The main concern was with missing data for income band where 7.3% of responses were missing. Multiple imputation was used, as described in the main text, but it is plausible that the income data were missing not at random (MNAR) if, for example, those with very low or very high income were less likely to disclose income, independent of other factors. To explore the potential impact of income data MNAR, three sensitivity analyses were completed, taking the imputed data for income and:

- Sensitivity analysis 1: A randomly selected 20% of imputed income values were set to the highest income band, to explore the impact of those with high incomes being less likely to disclose income
- Sensitivity analysis 2: A randomly selected 20% of imputed income values were set to the lowest income band, to explore the impact of those with low incomes being less likely to disclose income
- Sensitivity analysis 3: Of a randomly selected 20% of imputed income values half were set to the highest income band and half to the lowest income band, to explore the impact of those with low and high incomes both being less likely to disclose income

The results of the sensitivity analyses and of a model with no imputed data are presented in Table A1. Variations between models are minimal for most variables. As noted in the main text, when no imputation is used, there appear to be significant differences between generations, which disappears with imputation. This may be due to mediation, particularly through the perceived seriousness of the effects of climate change, which was included in the model but also had missing values. Variations between the main model (with multiple imputation) and sensitivity analyses are small. In some sensitivity analyses having a degree or higher qualification is significantly associated ($p < 0.05$) with WTP; in the main model a similar effect size is seen but the p value is slightly larger than 0.05.

Overall, if the income data are MNAR in the ways explored, it does not appear that this would have a large impact on the associations observed in the models.

Table A1: Comparison of models with and without multiple imputations for income group and sensitivity analyses for possible scenarios in which income data are missing not at random.

	Model with no imputation				Multiple imputation model				Multiple imputation sensitivity analysis 1				Multiple imputation sensitivity analysis 2				Multiple imputation sensitivity analysis 3			
	Odds ratio	95% CI		P value	Odds ratio	95% CI		P value	Odds ratio	95% CI		P value	Odds ratio	95% CI		P value	Odds ratio	95% CI		P value
Bid amount (per £10)	0.43	0.36	0.52	< 0.01	0.47	0.40	0.56	< 0.01	0.47	0.40	0.56	< 0.01	0.47	0.40	0.56	< 0.01	0.47	0.40	0.56	< 0.01
<i><u>Perceived seriousness of effects of climate change</u></i>																				
Extremely serious	1				1				1				1				1			
Fairly serious	0.35	0.26	0.46	< 0.01	0.35	0.27	0.46	< 0.01	0.35	0.27	0.46	< 0.01	0.35	0.27	0.46	< 0.01	0.35	0.27	0.46	< 0.01
Not very serious	0.08	0.05	0.14	< 0.01	0.08	0.05	0.13	< 0.01	0.08	0.05	0.13	< 0.01	0.08	0.05	0.13	< 0.01	0.08	0.05	0.13	< 0.01
Not at all serious	0.04	0.02	0.10	< 0.01	0.04	0.02	0.09	< 0.01	0.04	0.02	0.09	< 0.01	0.04	0.02	0.09	< 0.01	0.04	0.02	0.09	< 0.01
<i><u>Generation</u></i>																				
Pre-1946	1.20	0.82	1.75	0.34	1.08	0.76	1.53	0.66	1.07	0.76	1.51	0.71	1.08	0.77	1.53	0.65	1.08	0.76	1.52	0.68
1946–1965	1				1				1				1				1			
1966–1985	1.50	1.09	2.07	0.01	1.32	0.98	1.80	0.07	1.34	0.99	1.81	0.06	1.32	0.97	1.79	0.08	1.33	0.98	1.81	0.07
Post-1985	1.61	1.05	2.47	0.03	1.38	0.93	2.06	0.11	1.37	0.92	2.04	0.13	1.38	0.92	2.06	0.12	1.37	0.92	2.04	0.12
<i><u>Income band</u></i>																				
Under £7280	1				1				1				1				1			
£7280–£12479	1.14	0.77	1.71	0.51	1.15	0.78	1.68	0.48	1.15	0.78	1.68	0.48	1.17	0.80	1.72	0.41	1.14	0.79	1.66	0.48

£12480–£18719	1.73	1.13	2.66	0.01	1.72	1.14	2.59	0.01	1.72	1.13	2.61	0.01	1.77	1.17	2.66	0.01	1.72	1.13	2.61	0.01
£18720–£28599	1.24	0.82	1.88	0.30	1.24	0.83	1.85	0.29	1.22	0.82	1.81	0.33	1.26	0.85	1.89	0.25	1.22	0.82	1.82	0.32
£28600 and above	2.23	1.44	3.47	< 0.01	2.14	1.40	3.29	< 0.01	1.93	1.25	2.98	< 0.01	2.21	1.44	3.40	< 0.01	2.03	1.33	3.09	< 0.01
<i><u>Level of education</u></i>																				
Degree or above	1.28	0.92	1.78	0.15	1.37	1.00	1.88	0.05	1.40	1.02	1.93	0.04	1.36	0.99	1.87	0.06	1.39	1.01	1.91	0.04
Below degree	1				1				1				1				1			
None	0.84	0.59	1.20	0.35	0.80	0.58	1.12	0.20	0.79	0.57	1.10	0.17	0.81	0.58	1.12	0.20	0.80	0.57	1.11	0.18

HIGHLIGHTS

- Little is known about public support for policies to reduce the health risks of climate change
- This study suggests that British adults were willing to pay for such policies
- The perceived seriousness of climate change impacts was related to willingness to pay
- Those in higher income bands were more willing to pay than those with lower incomes
- Future research should investigate willingness to pay using other study designs

**Willingness to pay for policies to reduce future deaths from climate change:
evidence from a British survey**

Introduction

The health impacts of climate change on today’s populations are becoming increasingly evident (1, 2). Failure to keep global mean temperatures within 1.6° centigrade of pre-industrial levels will threaten the health of future populations (3, 4); projections point to increases in global temperatures by 2050 that are significantly above this threshold (5, 6). In the UK context, increasing temperatures are associated with an increased frequency and intensity of extreme hot weather and flooding; these climate change-related exposures have been highlighted as major risks to the future health of the UK population (7-10), with older people and children particularly at risk (7, 11, 12). The Climate Change Act (2008) sets the framework for climate governance in the UK, and mandates action on mitigation and adaptation (13, 14). Both offer significant co-benefits for public health (1, 15, 16) and are urgently needed to protect the health of future populations (5, 6). The health of future populations turns on the actions of today’s population and, in particular, on the speed and magnitude of the policy response to climate change (1, 6, 17-19). However, policies - and the economic evaluations that inform them - give greater weight to the wellbeing of current populations (20-22). A time weight (a discount rate) is applied when assessing the costs and benefits of policies, with future costs and benefits valued less highly than current ones. Discounting is designed to take account of the variable timescales over which costs and benefits are distributed (23). It is also seen to be in line with public’s preference to receive benefits now and ‘to defer costs to future generations’ (20).

It is increasingly recognised that standard discounting approaches are less appropriate for policies with long-term effects, including those with impacts on the climate system (22). However, little is known about public preferences for reducing climate change risks for those living in the future. One measure used to assess people’s preferences is their willingness to pay (WtP) to help meet the cost of such policies. WtP captures the value that an individual places on an outcome (for example, reduced health risks from climate change) in monetary terms, and reflects both the strength of their preference for the outcome and their ability and willingness to give up consumption of other goods to pay for it. We searched Web of Science up to December 2018 for WtP studies framed around the health risks of climate change (using the terms ‘health’, ‘climate change’ and ‘WtP’). We found very few studies, and no UK studies. For example, studies investigated people’s WtP to reduce climate-change related health risks from

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4 flooding in Switzerland (24), from variations in temperature in Taiwan (25) and from air
5 pollution in Pennsylvania (26); they indicated that communicating both the public health and
6 the climate change benefits of interventions increased people's WtP. Using a representative
7 British survey, we estimate people's WtP for policies to reduce future deaths in the UK that may
8 result from climate change.
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15 **Methods**

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18 Stated Preference (SP) methods provide a survey-based method for estimating the economic
19 value that people attach to outcomes for which there is not a direct market value (27-29), such
20 as protecting the health of future populations and improving the natural environment. One
21 widely-used SP method is contingent valuation (CV). This asks people how much they would be
22 willing to pay for a benefit in a hypothetical scenario, for example, if they would be willing pay a
23 specified monetary cost (e.g. £1 a month for 10 years) to support a policy that yielded a
24 specified benefit in X years' time (28). The use of SP methods in such contexts is supported by
25 official guidance on how to conduct appraisals of public policy initiatives such as climate change
26 policy (20). For our study, we used deaths, the most widely-used health measure and one
27 suitable for a general population survey (30). We derived our measure from the UK's national
28 assessment of future UK deaths from increasing global temperatures (7). This estimated an
29 additional 7,000 climate change-related deaths per year from heatwaves by the 2050s, with
30 additional, but uncertain, deaths from other climate change-related exposures, including from
31 flooding, worsening air quality and increased pathogens (7).
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40 Based on a representative British survey, we used CV to estimate people's WtP to reduce future
41 deaths that may result from climate change. The Opinions and Lifestyle Survey (OLS) is a cross-
42 sectional national survey governed by the UK Government's Statistics Authority Office code of
43 practice and overseen by the National Statistician's Data Ethics Advisory Committee (31, 32).
44 Our study was approved by the Department of Health Sciences Research Governance
45 Committee at the University of York.
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51 The OLS is based on a random probability sample of private households in Britain, drawn from
52 the Postcode Address File (PAF) containing approximately 26m addresses (32). Updated every
53 three months, the PAF is the most complete address database in the UK. The OLS sample is
54 stratified by region and socio-demographic profile. Socio-demographic stratification is based
55 on the proportions of: households with no car; households where the household reference
56 person has an occupation in a higher socioeconomic group; and people aged >65 years. The
57 survey runs eight months a year; a new sample is drawn each month and one adult per
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household is randomly selected for a face-to-face Computer Assisted Personal Interview. The survey consists of a standard set of socio-demographic questions, together with commissioned modules.

We commissioned a CV question in the January and February 2016 OLS on people's WtP for policies to maintain climate change-related deaths at their current level. Survey participants were asked whether they would be willing to pay ("yes"/"no") an ongoing monthly payment of a randomly assigned 'bid amount' of £1, £2, £5, £10 or £20 to hold climate change-related deaths at current levels rather than see such deaths increase (see Box 1); evidence indicates that binary choices result in a more reliable revelation of preferences (28). The range of bid values was determined from a pilot study, also using the OLS, where participants were asked to choose how much they would pay per month from a choice of £0, £1, £2, £5, £10, £20 or £50.

The question provided additional contextual information on the number of additional annual deaths expected by 2050 and one of two subsequent years (2080 and 2115) if no additional action was taken; and on the population groups most at risk (the elderly and the very young). This contextual information was provided in one of three forms (see Box 1) which were randomly assigned to respondents. Participants were also asked, after the question on WtP, 'how would you rate the seriousness of the impacts of climate change?' (hereafter 'perceived seriousness of climate change'). Response options were extremely serious, fairly serious, not very serious or not at all serious.

In line with the OLS average, the response rate across the months of our study was 50% (n= 1859). Analyses were performed using Stata version 15. An estimate of average WtP was obtained from the CV responses by fitting a univariate logistic regression to the binary responses (willing or not willing to pay) with the bid amount as the sole independent variable. To make the results representative of the general population, data were weighted to account of non-response bias and the probability of each respondent being included in the survey (32). Mean and median WtP were calculated from the coefficient associated with the bid amount in the logistic regression model (33, 34). A sensitivity analysis was also performed, in which all participants with unknown WtP (refused to answer or stated that they did not know) were assumed to be unwilling to pay.

A multivariate logistic regression was then used to assess the association of WtP with other factors. Candidate independent variables were: the bid amount; the respondent's perception of the seriousness of climate change; their generation of birth (pre 1946; 1946–1965; 1966–1985; post 1985); their individual gross income (split into five bands with approximately equal numbers of participants in each: less than <£7280, £7280–£12479, £12480–£18719, £18720–£28599, and ≥£28600); education (degree level or above, below degree level, none); health status (presence or absence of longstanding limiting illness); gender; parenthood status

(presence or absence of a child under 16 in the household); and the context offered in the question. Variables were added in turn and retained if they reduced the Bayesian information criterion (BIC) by more than 3. Multiple imputation with ten iterations using chained equations (35) with an ordered logistic model was used to handle missing data for income band and perceived seriousness of climate change. In addition to the candidate independent variables listed above, car ownership and employment status were also included in the imputation.

Results

The majority of respondents were willing to answer questions on their perceptions of climate change (98%) and their WtP to reduce climate change-related deaths (97%); the remaining responses were refused or answered 'do not know'. Among the other variables, only income had missing data (7%).

Perceived seriousness of climate change

Climate change was considered extremely or fairly serious by 86% of respondents (Table 1). Some variation was seen between sociodemographic groups. For example, 80% of the pre-1946 generation considered climate change to be extremely or fairly serious, compared to 92% of the post-1985 generation.

Willingness to pay to reduce climate change-related deaths

Overall, 61% of people were willing to pay the amount asked to reduce future climate-change deaths (Table 2). As the bid value increased, the probability that people were willing to pay this amount declined. A large majority (78%) were willing to pay if asked for £1 a month, compared with 46% of those asked for £20. The mean amount people were willing to pay was £19.71 (95%CI £15.64 - £22.70, Table 3).

The final multivariate model included the bid amount, perceived seriousness of climate change, birth generation, income band and level of education. Health status, parenthood status and context offered in the question (timescales for increased deaths and the elderly/very young as high-risk groups) did not improve model fit as measured by the BIC (nor did they have a statistically significant association with WtP) and were excluded. Income was associated with WtP to reduce climate-change deaths (Table 4); compared to people in the lowest income band, people in the highest income band were more than twice as likely to be willing to pay (OR 2.14, 95%CI 1.40–3.29). Perceptions of climate change were also associated with WtP, with respondents who considered it not at all serious being far less likely to pay than those who thought it was extremely serious (OR 0.04, 95%CI 0.02–0.09).

The findings were robust to sensitivity analyses assuming non-response to the WtP question indicated unwillingness to pay (Table 4) and also to modelled scenarios in which non-response to the income question was assumed to be missing not at random (Appendix). Multiple imputation changed associations significantly only in relation to generation of birth; without multiple imputation, post-1965 generations were more likely to be WtP than the 1946–1965 generation. This may reflect some bias introduced in the non-imputed model by the missing data. The lack of an association between WtP and birth generation may be due to mediation through perceptions of the seriousness of climate change and income, both included in the models. Uncertainty around perceptions of the future impacts of climate change has been identified as needing further investigation in WtP studies (24).

Discussion

The majority of study participants considered climate change to be a serious problem, a finding consistent with evidence that most adults in the UK are worried about climate change (36–38). Perceptions of the severity of climate change may be a result of the increase in extreme weather and flooding in the UK, and a consequent heightened sensitivity to the adverse impacts of climate change (39).

The majority (over 60%) were willing to pay to reduce the risk of future climate change-related deaths. Altruistic motives may partly determine WtP, including the value that people place on protecting the natural environment and future populations (26, 36, 40). Our CV question used additional deaths by 2050 as its baseline scenario and included future timescales ranging from 2080 to 2115; the majority of study participants were also alerted to the very young being at particular risk. None of these contextual factors were significant predictors of WtP, suggesting that there was no significant additional discounting for avoidance of deaths further into the future. The presence of children in the household was also not a significant predictor of WtP, suggesting that WtP was not tied specifically to concern about the future welfare of one's children.

WtP was significantly associated with perceptions of climate change. Those who thought climate change to be a more serious problem were more willing to pay for policies to reduce to address it, a finding consistent with other WtP studies (24,18). The connection between perceptions of climate change and WtP has been attributed to a sense of responsibility for the environment and future generations as well as a desire to reduce one's own exposure to climate-change risks (24, 26, 36).

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People were less willing to support policies to address climate change-related risks to health as the cost to them increased. There is evidence that the public support action on climate change at the national and international levels, but oppose tax policies that would affect them directly (41). WtP was lower for those in the lowest income band compared to the highest, a pattern found in most (24, 25, 36), but not all (26), studies. Studies of the relationship between household income and stated willingness to pay typically reveal rather low elasticities (less than unity) (42). Lower WtP among those on lower incomes may not reflect lower concern, but simply lower ability to pay. Meeting the costs of climate change through progressive systems of taxation (e.g. income tax) could provide an equitable approach to funding these policies.

Some limitations of the study should be noted. Firstly, people's perceptions of climate change and therefore their WtP to reduce its health impacts may be related to factors beyond the scope of our study, including an individual's experience of extreme weather events (39) and concerns about non-health related impacts of climate change such as damage to property and infrastructure (43, 44). Context is important in encouraging concern and WtP for policies to address climate change (45, 46). However, in our study, variations in the contexts presented were not associated with a significant change in WtP. WtP was not affected by whether the very young were said to be at particular risk in addition to the elderly; neither was it affected by the timeframes and severity of the projected impacts. This may reflect a low discount rate among respondents, such that avoided deaths in 2050 were not viewed as significantly more desirable than avoided deaths in 2115. Across such long time periods, intra-generational time preferences (an individual's preference for the timing of benefits across generations) may be a factor (18, 47). The low discount rate may also reflect a lack of information on how the risk reduction would be achieved in practice. An individual's WtP may be policy-sensitive, influenced, for example, by perceptions of and preferences for climate change mitigation and adaptation (48), as well as by views on the effectiveness and fairness of such policies (49). Including such potential influences on WtP was not possible using our chosen study design (questions inserted into a general survey) but would merit further investigation. We would also seek to explore non-WtP in greater depth. Of those asked to pay £1 per month, one in five were unwilling, a proportion rising to four in five among those who considered the effects of climate change to be not at all serious. Finally, our cross-sectional study predates the recent increased public debate about climate change action; given increasing public concern about climate change (50), a follow-up study may find a larger majority of adults willing to pay to reduce its future health impacts.

Secondly, SP methods may elicit responses that are not in line with real choice behaviour. In particular, WtP is estimated from questions based on hypothetical scenarios; study participants may therefore not regard their responses as consequential (as having real world consequences). Our question on the perceived seriousness of climate change provided an

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4 indication of whether the individual believed in and cared about the scenario; these affective
5 attributes have been found to be associated with respondents regarding the scenario as one
6 likely to be implemented (51). Nonetheless, a study where participants believed they would be
7 required to pay if the proposed policy secured popular support – for example, a study linked to
8 a public consultation on policy options – would be an important next stage in establishing
9 people's WtP to reduce the future health risks of climate change, since we know from other
10 work that consequentiality is an important aspect of demand revelation in SP methods (51).
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15 SP methods are the only ones available for estimating economic values for which there is not a
16 market value or other data based on people's behaviour (28) (for example, a policy experiment
17 enabling comparisons to be made between exposed and non-exposed populations). We
18 followed standard SP guidelines for survey design, including the identification of a
19 representative sample of the potentially-affected population, a single binary-choice question
20 (yes/no) that included a baseline 'status quo' condition (the current number of deaths),
21 designation of who pays ('you'), payment amounts and frequency, a change mechanism (a
22 policy intervention) and a defined benefit (reduced climate change-related deaths at specific
23 points in time) that, since it was based on official estimates, would be likely to be deemed
24 credible by survey participants. The question was also piloted in an earlier ONS survey to
25 ensure it was understood by the study participants.
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33 **Thirdly, our study explored associations between WtP and income, generation and education.**
34 **All three factors were included in our final model, and model fit supported their inclusion.**
35 **While it is possible that there are interactions between the factors, sample sizes were**
36 **insufficient to fully explore this. However, such possible interactions do not impact on the main**
37 **aim of our study: to assess population-level WtP for a defined future public health benefit**
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41 Our study had a number of further strengths. As well as being based on a representative survey
42 of adults in Britain using individual home-based interviews, it collected a range of socio-
43 demographic data, including educational attainment, income and parental status, enabling
44 analysis of their association with WtP. There were few missing data for most variables used in
45 the models. As missing data in variables used in the multivariate model may bias estimation,
46 mean and median WtP were estimated from the univariate model; using data imputation,
47 mean and median WtP were also estimated from the multivariate model and the 95% CIs of
48 these estimates included the point estimates from the univariate model provided in Table 3.
49 The sensitivity analyses, which treated all missing data on WtP as refusal to pay, set a lower
50 bound on the WtP estimates that were not significantly different to those from the main model.
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57 Across a range of scenarios, respondents expressed a WtP to reduce future health impacts of
58 climate change, suggesting that health, including the health of future populations, is an
59 outcome that people value (1, 18, 24, 40). Such a health framing is supported by evidence of
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the adverse health impacts of climate change and the opportunities for health co-benefits of mitigation and adaptation, particularly for future populations (1, 15, 16). However, although the Paris Agreement to strengthen the global response to climate change recognised the right to health (52), health remains marginal to climate change policies and public debate (1, 53). In this context, public support for climate change policies that yield health benefits underlines the important role to be played by the public health community in accelerating national and global action on climate change (1, 54).

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Dear Editors

Willingness to pay for policies to reduce future deaths from climate change: evidence from a British survey

We are pleased to submit our revised paper for consideration for publication in *Public Health*. Our revisions address the points raised by the two reviewers.

We are also submitting our response to the reviewers' comments. We detail our responses in bold in the 'response' document. Changes to the paper are put in yellow highlight – all are additions to the paper.

We look forward to hearing from you.

Yours sincerely

Hilary Graham

Manuscript Number: PUHE-D-19-00143

Manuscript Title: Willingness to pay for policies to reduce future deaths from climate change: evidence from a British survey

Response to the reviewers' comments (our response is in bold)

We thank the two reviewers for their very helpful and constructive feedback. Our response is detailed in bold under the points they make. Changes made to the paper are put in yellow highlight – all are additions to the paper.

Reviewer #2:

The paper is of interest as it provides results of a survey conducted on public perception and willingness to pay to reduce the impacts of climate change. However, it mainly focused on the economic and monetary aspect and not on what public health measures or adaptation strategies the investments should be focused on which would have been more informative and relevant in the context of climate change. It is well established that the British population is aware and conscious about the potential risks of climate change, what they think is of greater importance in terms of mitigation or adaptation measures in PH, which is a small part of a much greater picture is less known.

The public health aspect should have been developed further and a better focus on what to invest on would have made the paper more interesting and given a real insight on the public's preferences for reducing climate change risks.

We thank the reviewer for their feedback. We have given more emphasis to the public health aspects of climate change and to climate action (mitigation and adaptation) in the Introduction and the Discussion.

With respect to investigating the public's views on different policy options for addressing the health risks of climate change (mitigation/adaptation), this was not with our study design (questions inserted into a general survey). We make this point more clearly in the Discussion.

Generation or age of respondents influences both income and level of education. The very young will less in the very rich category by definition and level of education has also changed over time and may reflect income in different ways. Also priorities in life in the population need to be considered, here we include young adults, adults with families, pensioners etc that have different needs and priorities in terms of allocation of economic resources as well. These aspects need to be taken into account in the model and mentioned in the limitations. The perception of climate change may also be different in the case-mix of the population. Asking low income subgroups to pay for anything is a critical issue as they do not have the means to do so, so their response is biased by this fact. While high income individuals make a choice based on different criteria. It is not just summed up in the amount they are willing to pay.

The reviewer raises interesting points regarding the complex interactions between generation, education and income, all of which would be expected to co-vary to some extent. Our final model included all of these variables and model fit, measured by BIC, supported the inclusion of all three, suggesting that each provided additional information on WtP – i.e. differences in generation were still important within groups that had the same education and income levels. There were not sufficient data in this study, but it would be interesting in a future, larger, study to include interaction terms in the model to see whether, for example, education level had a different association with WTP depending on income group or generation. This has now been noted in the Discussion section.

With regard to the second point about different needs and priorities, this is now acknowledged in the revised discussion section. WtP is the term commonly used in these types of studies, but it is of course also a reflection of ability to pay – this study captures what individuals would be willing *and able* to pay (what economists refer to as “effective demand”); it is therefore possible that those in low income groups put a high priority of preventing future heat-related deaths but lacked the ability to pay the higher amounts. However, the primary focus of this study was to determine what, at a population level, would be acceptable as a cost of avoiding future heat-related deaths (influenced by many factors, including income) and not to measure whether and to what extent ability to pay acted as a constraint on WtP.

Moreover, we would point out that, when economic values for health impacts are used as an input to cost-benefits analysis of climate policy measures (as is recommended in UK government guidelines in the most recent issue of the Treasury Green Book), then it is critical to include estimates of benefits which are consistent with market-valued costs and benefits. This means using a measure of preferences backed up by ability to pay – that is, willingness to pay as reported here. As we say in the paper, “WtP captures the value that an individual places on an outcome (for example, reduced health risks from climate change) in monetary terms, and reflects both the strength of their preference for the outcome and their ability and willingness to give up consumption of other goods to pay for it”. We control for variations in ability to pay by including income on the right hand side.

The discussion should be broadened to include the policy aspects currently being discussed in terms of climate change and public health, such as climate change mitigation and health co-benefits (Lancet Commission on health and climate change), Sustainable Development Goals (UNEP).

We thank the reviewer for this suggestion. We now refer explicitly to forms of climate action (mitigation and adaptation) in the Introduction and Discussion. However, as noted in the paper (and in our response above), our study did not have the capacity to investigate public preferences for different forms of climate action to protect the health of future populations. We acknowledge in the paper that this would be an important next step.

Reviewer #3:

Really important topic, which is currently inadequately explored. This research makes a useful contribution to the debate by exploring the public perception of future events. Of course, since the work reported here, events like Extinction Rebellion may have improved the picture somewhat.

We have taken this helpful comment on board. In the Discussion section, we make this point and note that a follow-up study may find a larger majority of adults willing to pay to reduce its future health impacts.

Methodology - sound and well described

Findings well described.

My only comment would be that it would be nice to have had a little more discussion of the discounting findings - are both 2050 and 2115 too far in the future for respondents, so that similar discounting is applied to both?

We thank the reviewer for this suggestion. We now discuss this point in more detail, noting that, across such long time periods, intra-generational time preferences may come into play (and adding references to support this).