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Eliciting trade-offs between population health and environmental outcomes: A pilot study

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ABSTRACT

Objectives: The aim of this study was to investigate whether it is possible to elicit how United Kingdom (UK) public citizens might trade off human health and environmental outcomes.

Methods: Using a representative adult population, a discrete choice experiment (DCE) was conducted on criteria impacting trade-off decisions between human health and environmental outcomes. Respondents were asked to make twelve choices that included four attributes: the impact on UK life expectancy, the impact on biodiversity, the impact on UK carbon emissions and location of environmental impacts. Data were analyzed using a conditional logit regression model.

Results: 508 respondents completed the survey. A DCE found UK public citizens are willing to forgo human health to reduce environmental harm.

Conclusions: This research demonstrated it is possible to elicit the public's view about trade-offs between health and the environment. Moreover, the public is willing to forgo human health to reduce environmental impact, propounding the importance of healthcare sustainability.

Keywords: healthcare, environmental impact, public opinion, trade-off

INTRODUCTION

Anthropogenic effects on climate change are one of the greatest public health threats. From global warming to the biosphere and deforestation, pollutants including the ubiquitous use of plastics and pharmaceuticals, to dangerous effects on nitrogen cycles and freshwater: six of nine planetary boundaries have been crossed [1]. In 2024, Earth experienced a 12-month period of average global temperature more than 1.5 °C above the pre-industrial reference period [2]. Without action, global healthcare emissions are projected to more than triple by 2050 to six gigatons a year, increasing average global temperature by up to 5.7 °C if we collectively continue along the same trajectory of greenhouse gas (GHG) emissions [3]. Rapid reductions in GHG emissions may stop or slow this increase in global temperature.

Previous research has linked climate breakdown to ill health, contributing to adverse pregnancy outcomes and worsening of underlying cardiovascular and respiratory diseases [4]. The healthcare industry itself contributes to environmental damage, accounting for 4.4% of total GHG emissions [5]. Converted into disability-adjusted life years (DALYs), the emissions from the global healthcare sector alone are reported to contribute to an annual loss of up to 3 million DALYs [6, 7]. In the UK, pharmaceuticals and medical devices constitute 20% and 10%, respectively, of the 25 million tonnes of total GHG emissions generated by the NHS each year [5]. As part of the UK government net zero targets, the NHS has set an ambitious target to reach net zero by 2045 [5]. Significant co-benefits can be achieved through healthcare net zero including improved healthcare delivery and more timely diagnostic intervention. For example, implementation of digital health technologies can concurrently reduce carbon emissions across a care pathway, promote patient empowerment and lead to earlier diagnosis [5].

Given the urgent need to reduce GHG emissions to mitigate the worst impacts of climate change, in combination with increased political pressure to meet legally binding legislation, there is a necessity for regulatory mechanisms to prioritise sustainable development of healthcare [8, 9]. The UK government social value model for commissioning and purchasing of NHS goods and services and the NHS England net zero supplier roadmap are key developments to support the introduction of environmental sustainability considerations in healthcare decision-making [10, 11]. At the same time, health technology assessment (HTA) organisations such as NICE have pledged to develop approaches to

Table 1. Changes made to the DCE design based on the focus group feedback and the justification

Change made following the focus group	Justification
A cheap talk script was added before respondents faced the choice tasks	Added as an ex-ante measure to reduce hypothetical bias
A link to the attribute definitions and hypothetical policy was added to every choice task	Allowed respondents to refer back to the provided information when answering the choice tasks to ensure well-informed decisions
Prewarned respondents that the survey used comprehension question to encourage engagement	Included as a courtesy to respondents
The hypothetical policy was explained on a separate page	Improved the clarity and salience of the hypothetical policy description making it easier for respondents to read and digest
Reworded the carbon emissions definition to make the consequences of increased emissions more salient	Addressed feedback that the consequences of the carbon emissions attribute were unclear
Included the number of births in the definition of the UK life expectancy attribute	Done to emphasise the societal nature of the attribute

incorporate environmental sustainability amongst their portfolio of work, whilst maintaining a healthcare perspective [12]. Research shows that public opinion and acceptance are critical for the mainstay of any new policy [13]. In 2023, NICE published a report exploring public opinion on their role in supporting healthcare sustainability[14]. Highlights included the public entrusting NICE to continue to explore techniques that will positively influence sustainability in the healthcare supply chain and to maximise population health outcomes through shared decision-making [14]. Knowledge of public preferences is important for assessing priorities between healthcare decision-making and environmental care. Furthermore, by taking public preferences into account, decision-making can be optimised to support greater societal benefit. However, a recent Italian report studying public trade-off between human lives, individual freedoms, and the economy while coping with a public health crisis, showed a preference to avoid income losses over saving human lives [15].

The objective of this study was to determine whether it is feasible to elicit opinions from United Kingdom (UK) public citizens around trade-offs between human health and environmental outcomes, and whether the location of the environmental consequences affects public preference. A discrete choice experiment (DCE) was developed to estimate the magnitude to which members of the public are willing to trade off different factors including human health, GHG emissions, extinction of species, and the location of those effects.

METHODS

Study Design

DCEs are a commonly used tool to elicit preferences for health [16]. The method is an attribute-based measure of benefit, based on the assumptions that healthcare's interventions, services, or policies, can be described by their attributes [17]. Participants undertaking a DCE are asked to choose between two or more alternatives with resulting choices revealing an underlying (latent) utility function [17]. The approach combines random utility theory, econometric analysis, consumer, and experimental design theory [18]. Further details on conducting a DCE and theoretical considerations can be located in other literature [19, 20]. A sample of UK adults (⩾ 18 years old) was recruited by Qualtrics: a market research company. The study sample was designed to be generalized to the entire UK adult population. The online survey was conducted in August 2023. Attributes and levels for the DCE were selected using insights from a targeted literature review and the opinions of the research team. The attribute selection process focused on capturing preferences for human health, the environment, and the location of environmental impacts. The four attributes chosen were:

(1) UK life expectancy,

(2) endangered species,

(3) UK annual carbon emissions, and

(4) location of environmental impacts.

Before the main DCE survey, the survey was initially piloted on a focus group sample (n = 35). In the focus group, the median completion time of the survey was 17 minutes. Overall, the focus group feedback indicated that the content, layout, and number of choice tasks presented were suitable. A feedback form was shared with the focus group prior to the survey collection. Changes were made to the survey based on the feedback from the focus group, as shown in **Table 1**.

For the main DCE survey, it was planned to include 500 participants from the UK. Respondents were presented with either 12 or 13 different choice tasks, and for each choice task they had to choose which of the 2 possible alternatives they preferred (scenario A or scenario B) described in terms of four attributes and various numbers of levels (see **Table 2** and **Figure 1**). Participants had to agree to an electronic informed consent form before they could proceed with the 20-minute web-based DCE survey. Screening questions were used before the experimental choice tasks to confirm eligibility, including UK residency status and to ensure that participants were aged 18 and over.

Experimental Design

This DCE was constructed using a good research practices checklist, to ensure the reliability and transparency of this study's findings [21]. A full factorial design (FFD) includes all of the possible combinations of levels and attributes. Given the number of attributes and levels selected for this study, a FFD would have generated 90 choice tasks, which was impractically large. Therefore, a fractional factorial design (FrFD) was used to select a subset of all possible combinations to reduce the number of choice tasks faced by participants, thus mitigating high response inefficiencies.

Table 2. Attributes and their associated levels used in the final survey

Atrribute	Level
The impact on UK life expectancy	• 1 year increase (+1.2% increase) • No change • Year decrease (-1.2% decrease)
The impact on endangered species	• 100 species saved from extinction • No change • 100 species lost to extinction
The impact on UK annual carbon emissions	• 10% reduction in carbon emissions (equivalent to annual emissions of 6.4 million people) • 5% reduction in carbon emissions (equivalent to annual emissions of 3.2 million people) • No change in carbon emissions • 5% increase in carbon emissions (equivalent to annual emissions of 3.2 million people) • 10% increase in carbon emissions (equivalent to annual emissions of 6.4 million people)
The location of environmental impacts	• Within the UK • Outside the UK

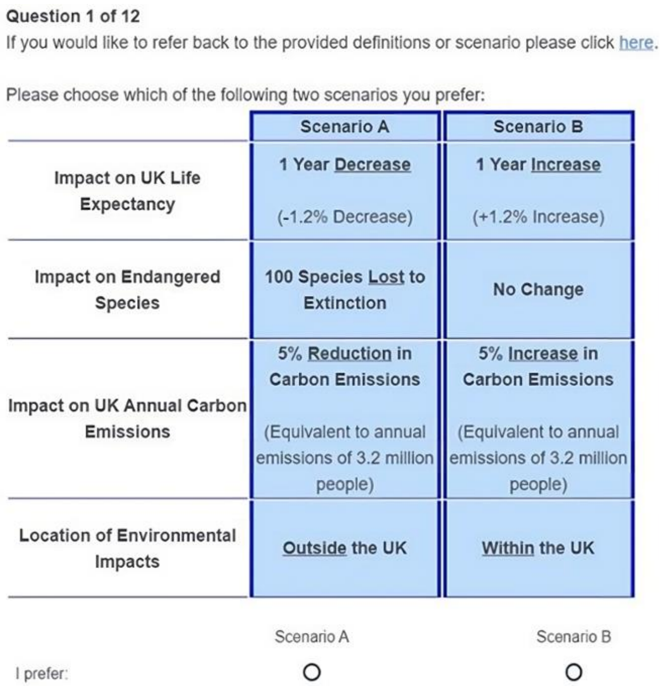

Figure 1. Example choice task used in the survey (Source: Authors' own elaboration)

The FrFD was constructed manually using an orthogonal main-effects plan that produced the smallest number of total choice sets, given the number of attributes and levels selected. The modular arithmetic shifted design subsequently applied was the one that produced the least dominated choice tasks, under the a priori assumption that the best level for the location attribute was 'within the UK'. A total of 25 choice sets were generated and divided into two blocks with 12 and 13 choice tasks, to minimize respondents' cognitive burden. Each respondent was assigned to one block randomly.

In each choice task, two alternatives were presented. Unlabeled alternatives were used since no realistic titles existed. Respondents were asked to select their preferred scenario from the two alternatives. The choice task combinations in this survey were hypothetical. Automatic survey quality control was applied by Qualtrics. Responses termed "speeders" were flagged when they were more than two standard deviations from the median duration it took for respondents to complete the survey.

The questionnaire survey instrument included the following sections:

- Study information: explaining the purpose of the research, what participation would involve, the estimated time to complete the survey and obtaining respondent consent.
- Screening questions, based on inclusion criteria.
- Background information on climate change, including information on the causes and impacts of climate change, and information on the UK Government and NHS's carbon emissions commitment.
- Respondents' demographic and socioeconomic information (including highest level of education, employment status and marital status).
- Introduction to the hypothetical choice content, definitions of all the attributes and relevant levels and explanation of the choice tasks, followed by presentation of choice tasks.
- An open-ended question asking for any further information on participants thoughts on climate change.

During the focus group pretesting, hypothetical bias (the difference between stated and real values) was identified. To reduce this, before the choice sets were presented, participants were provided with a short "cheap" script that explained hypothetical bias, prompting participants to make realistic choices in the survey. Following the completion of the choice tasks and to avoid influencing their choices through contextual effects, respondents were asked to self-report if they agree, neither agree/disagree or disagree to being "environmentally conscious" [22].

The levels of the attributes were selected based on a 7-year timeframe (i.e., the attributes describe a policy where the impacts would be fully realized in 7 years' time). This timeframe was chosen because it was sufficiently distant for all the attribute-levels to be plausible, but not too distant for respondents to value the impacts substantially lower due to positive time preference and discounting.

UK life expectancy was selected to capture people's preferences for human health at a societal level. Life expectancy was expected to be familiar with the general public, and explicitly using the national average was hoped to highlight the societal trade-off occurring. From 2009 to 2019, the UK's average life expectancy increased by 1.4 years [23]. Therefore, from a societal perspective it felt justified a 1-year change in average life expectancy was a realistic magnitude for the change in levels.

Endangered species was selected to capture people's preferences regarding the biodiversity aspect of the environment. The number of endangered species was used because the number of species was expected to be the most digestible to the public. In addition, endangered species are close to extinction, increasing the tangibility of the attributes trade-off. 100 endangered species being saved from, or lost to, extinction was considered drastic enough to ensure respondents considered this attribute when selecting between choice tasks.

UK annual carbon emissions was selected for two reasons. First, carbon emissions are the prominent target for government environmental policies, as well as international commitments such as the Paris Agreement signed by 196 parties at the 21st United Nations Climate Change Conference (COP21) in Paris, 2015 [24]. Secondly, methods already exist for quantifying carbon emissions, making it a viable and relevant way to incorporate environmental impacts into the HTA process [6].

From 2010 to 2020, UK GHG emissions were reduced by 32% [25]. Therefore, a 10% change in carbon emissions over 7 years was considered to represent a plausible scenario. The carbon emissions attribute included an additional increase and decrease level to assess if participant preferences were more responsive to either the magnitude of emission change or to the direction of change. Alongside the percentage change in emissions, the levels were also quantified as the equivalent annual carbon emissions of a given number of people. This presentation decision was made to help respondents better conceptualize the magnitude of change in carbon emissions.

The location of environmental impacts distinguishes between UK impacts and worldwide impacts. This was considered important because it captured how the location of the environmental spillover influenced respondent preferences. To support respondent comprehension, they were informed multiple times that direct environmental actions taken by the UK government, would not necessarily translate into direct environmental benefits within the UK.

Statistical Analysis

Statistical analyses were conducted using Stata 18.0. The DCE preference data was analyzed using a conditional logit regression within a random utility maximization framework. Random errors were assumed to be independently and identically distributed with a type I extreme distribution.

The carbon emissions, endangered species and location attributes entered the model as dummy-coded categorical variables, capturing the effects of discrete changes in the levels. The reference category for carbon emissions and endangered species was 'no change', and for the location attribute it was 'within the UK'.

The specification of life expectancy as a continuous variable was informed by a comparison of the regression results where life expectancy was modelled as a continuous variable with the regression results where life expectancy was modelled as a categorical variable. A Wald test failed to reject the appropriateness of a linear continuous specification for life expectancy, implying that the effect of a 1-unit change was assumed to be constant [26].

To calculate the trade-offs between different attributes, the marginal rate of substitution (MRS) was used. The MRS indicates how much of one attribute a person is willing to give up for an improvement in another attribute, holding all else constant. The coefficient of each categorical attribute was divided by the coefficient for life expectancy.

To ensure that the results of the DCE had sufficient statistical power to perform statistical analysis, a minimum sample size is required. As there is no standard approach to determine the minimum sample size necessary, the 'rule of thumb' proposed by Johnson and Orme was used, resulting in an estimated minimum sample size of 52 participants [27].

Table 3. Sample baseline characteristics

Characteristics	Sample	Population statistics[a]
n	508	-
Age (%)		
18-24	15.2%	10.6%
25-34	24.8%	17.2%
35-44	27.4%	16.6%
45-54	18.3%	17.0%
55-64	9.5%	16.0%
65 and over	4.9%	22.6%
Sex (%)		
Male	32.5%	48.4%
Female	67.5%	51.6%
Employment status (%)[b]		
Economically active	71.7%	58.3%
Student	4.9%	7.9%
Retired	6.7%	21.6%
Economically inactive	16.7%	12.1%
Highest qualification (%)[b]		
First degree or higher	37.6%	33.8%
College	26.2%	16.9%
High School or lower	25.2%	41.2%
Other (inc. apprenticeship)	11.0%	8.1%
Marital status (%)[b]		
Marital or in a civil partnership	46.7%	44.6%
Single	40.9%	37.9%
Other	12.4%	17.5%
Self-described as "environmentally conscious"		
Agree	62.3%	-
Neither agree nor disagree	33.4%	-
Disagree	4.3%	-

Note. [a]Population statistics taken from the 2021 census data [36] & [b]Population statistics include ages 16 plus [36]

RESULTS

In total, 508 respondents completed the survey. No respondents were excluded (flagged as speeders) from the final survey. Table 3 shows how the baseline characteristics of the sample compared with the general population. In the overall sample, females were overrepresented (67.5%), while people aged 55 and above were underrepresented (14.4%). The majority of respondents (62.3%) self-described themselves as being environmentally conscious [28]. The median and mean

Table 4. Conditional logistic regression results

Conditional logistic regression	Number of observations	Log likelihood	Pseudo R^2
	12,696	-7,169.3514	0.0882
Attribute	**Level**	**Coefficient**	**Standard error**
Life expectancy		0.3118***	0.0223
Endangered species	100 species lost to extinction	-0.8999***	0.0447
	100 species saved from extinction	0.4857***	0.0444
Carbon emissions	10% increase	-0.4562***	0.0581
	5% increase	-0.4946***	0.0581
	5% decrease	0.2339***	0.0592
	10% decrease	0.1490**	0.0582
Location of environmental impact	Outside the UK	-0.1507***	0.0369

Note. ***p < 0.01; **p < 0.05; & *p < 0.1

Table 5. Marginal rates of substitution

Attribute	Level	Marginal rate of substitution	Standard error
Life expectancy		N/A	N/A
Endangered species	100 species lost to extinction	-2.8856***	0.2502
	100 species saved from extinction	1.5576***	0.1776
Carbon emissions	10% increase	-1.4628***	0.2123
	5% increase	-1.5860 ***	0.2178
	5% decrease	0.7502***	0.1961
	10% decrease	0.4777**	0.1894
Location of environmental impact	Outside the UK	-0.4831***	0.1233

Note. ***p < 0.01; **p < 0.05; & *p < 0.1

time taken to complete the survey was 6 minutes and 56 seconds and 8 minutes and 28 seconds, respectively.

The output of the conditional logit regression is shown in **Table 4**. Lower carbon emissions and saving endangered species increased utility compared with no change. Similarly, higher carbon emissions and endangered species becoming extinct decreased utility compared with no change. Utility also fell when the environmental impact occurred outside the UK, as opposed to within the UK, while higher UK life expectancy improved utility.

The saving of endangered species had the largest positive impact on utility, while the extinction of endangered species had the largest negative impact, although it should be noted that these are measured on different scales. A Wald test showed that the estimated coefficient of 100 endangered species becoming extinct versus no change, was statistically equal to twice the negative estimated coefficient of saving 100 endangered species versus no change.

Table 5 shows the estimated MRS for each level. In order to have the same effect as 100 species lost to extinction, life expectancy would have to decrease by 2.9 years, whereas to have the same effect as 100 saved species from extinction, life expectancy would have to increase by 1.6 years (versus no change). Similar patterns can be seen for carbon emissions whereby an increase in carbon emissions is equivalent to a decrease in life years and vice versa, compared with no change. A compensation 0.5 years of life expectancy is acceptable to experience the same environmental impact within the UK compared to ‘outside the UK’.

DISCUSSION

This study used a DCE to determine whether it is possible to elicit opinions from UK public citizens as to whether they are willing to trade life expectancy in order to gain environmental improvements. The results indicate that this method is feasible, and that environmental sustainability in healthcare decision-making is important to the public.

To the authors’ knowledge, by including a variety of environmental outcomes, this research is the first to show that environmental policies based on decisions focusing only on carbon emissions are likely to undervalue the public’s preference for the environment. In addition, limited environmental scope may be less successful in the longer term than the inclusion of broader environmental outcomes such as impact on species, water pollution and resource depletion. Moreover, policies that trade off human health losses for environmental gains might be publicly tolerable, provided that the cost (i.e., in terms of lost health) is within certain thresholds. Therefore, a holistic approach that incorporates a broad set of environmental outcomes into HTA, may better represent public preferences and result in more optimal decision-making.

This study supports previous research that the public agrees to including environmental sustainability considerations in healthcare decision making [29] and goes further to demonstrate that it is possible to quantitatively elicit the extent to which trade-offs will be accepted. Moreover, this study shows that receivers’ perspectives should not be regarded as potential barriers, but as a facilitator for transitioning toward sustainable healthcare.

There will be an inevitable trade-off between broadening the scope of the environmental impacts considered in HTA, and the increased complexity and costs needed to measure them. Therefore, given government policy targets are set in terms of carbon emissions and that methods to quantify carbon emissions already exist, McAlister et al. suggests incorporating carbon emissions into HTA initially, and gradually expanding the scope of environmental impacts in the future [6]. This approach is aligned with the findings of the present study, in that a greater scope of environmental consequences will capture the publics true preference for the environment.

This study quantifies the magnitude to which UK public citizens are prepared to trade off human health with environmental outcomes. Therefore, this research provides new data in an area that is nascent of research and helps to inform decision-makers on how to design strategies to address healthcare sustainability.

Care should be taken regarding interpreting the results beyond the included sample. Compared to the general population, the final sample included more people with the highest qualification level and more economically-active people. This reflects the challenge across research studies in recruiting participants that represent the general population.

It should be noted that the development of attributes and levels used in this pilot study were based on a pragmatic literature search and the knowledge of the research team. Misspecification of attributes and levels may lead to erroneous results [30]. Therefore, to better capture the relevant attributes and levels, an extensive literature search or systematic review should be considered and the use of expert knowledge and the general population during the attribute development stage.

Whilst this study explored explicit trade-offs between population health (life expectancy) and environmental outcomes, the two are likely to be closely entwined. Harm to the environment can directly lead to human ill health, loss of human life and a reduction in quality of life [31-33]. This effect was not accounted for in the survey because it was felt that attempting to quantify a relationship would distract from the main purpose of the experiment (e.g., to understand whether or not, and to what extent, trade-offs would be acceptable). It is possible that some respondents considered this effect when answering the questionnaire.

The response time of respondents is an important consideration when conducting a DCE. The median response time for the DCE survey was shorter than expected, meaning respondents may not have allocated sufficient time to undertake the survey. While the relationship between response time and data quality is ambiguous, novel approaches can be used to explore the effects of response time on the utility coefficient estimates [34].

Limitations of the conditional logit model include scale and preference heterogeneity [26]. Unobserved preference heterogeneity may arise from differences in decision making processes, or from differences in climate change perceptions [35]. Therefore, if there are unobserved systematic variations in preferences across respondents, the estimated coefficients may be biased [26]. Observable characteristics were not controlled for in the conditional logit regression due to the time frame for this pilot study. Furthermore, given the model's inability to account for unobservable preference heterogeneity, not controlling for observable characteristics will likely exacerbate any bias. However, even if the observable heterogeneity was well controlled for, unobservable preference heterogeneity may still arise. There are several alternative methods that can be applied to overcome the limitations of conditional logit models, including random parameters logit models and latent-class finite-mixture models [26].

Finally, this study was designed as an exploratory pilot. Whilst the study has shown that preferences for trade-offs can be quantified, it is not suggested that the values presented in the paper be used to inform policies. Given the limitations of the study, further research is required to gain a robust estimate of the true preferences for such trade-offs.

CONCLUSIONS

As climate change continues to worsen and evidence grows showing the negative environmental impact of healthcare, understanding public preferences in terms of the trade-off between human health and environmental outcomes is important. This study's results indicate that such trade-offs are tolerable to the public. It also suggests that environmental policies that solely focus on carbon emissions are likely to undervalue the public's preference for the environment and may be less successful longer term than the inclusion of more holistic environmental outcomes.

Author contributions: MP, EB, & MT: concept and design, critical revision of the paper for important intellectual content, and supervision; **MP & EB:** administrative, technical, or logistic support; **MP:** drafting of the manuscript; **CM & EB:** analysis and interpretation of data; & **CM:** acquisition of data. All co-authors agree with the results and conclusions.

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Ethical statement: The authors stated that the survey was carried out via Qualtrics on members of the general population. The data were downloaded from Qualtrics' platform. Qualtrics' platform and data handling procedures have achieved ISO 27001, 27017, 27018 and 27701 certification and are compliant with the General Data Protection Regulation (GDPR). The authors further stated that no personally identifiable or sensitive data were collected, and responses were fully anonymised. Only aggregated data were reported.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

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