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CLIMATE CHANGE, LARGE RISKS, SMALL RISKS, AND THE VALUE PER STATISTICAL LIFE

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Climate Change, Large Risks, Small Risks, and the Value per Statistical Life

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Abstract:
We conduct a contingent valuation survey in Spain and the UK to elicit information about the Willingness to Pay (WTP) for heat wave watch and response programs. We find that people are willing to pay for such programs, and that the WTP (€ 50 for each of 10 years; 2019 PPP euro) is virtually the same across the two countries and across respondents that received two alternate presentations of the mortality risks with and without the programs. The responses to the WTP questions are internally consistent. Persons who re-assessed their own risks as "very high" after reading the questionnaire's information about the health effects of excessive heat are prepared to pay more for these programs. These persons are in poor health and less highly educated, and thus an important priority for outreach and education efforts by heat wave watch and response programs. That people value saving lives during heat waves as important is confirmed by the results of person tradeoffs, which show that avoiding a fatality during heat waves is comparable to avoiding a cancer fatality, is slightly more valuable than an avoiding a cardiovascular fatality, and definitely more valuable than an avoided road traffic fatality. The Value per Statistical Life implied by the WTP for the programs is € 1.1 million to € 4.7 million (2019 PPP euro), depending on the size of the mortality risk reduction valued by the respondent, for an average of € 1.6 million.

JEL: Q51; Q54; Q58; K32
Keywords: Climate Change; Heat Waves; Health Risks; Value per Statistical Life (VSL); Life-saving Programs

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1. Introduction

Global data indicate that July 2023 was the hottest month on record. By the end of the month, the city of Phoenix in Arizona had recorded 31 consecutive days with temperatures above 110° F (43.3° C). More than 150 million people in the US across over 30 states were under heat alerts due to extreme temperatures on Thursday, July 27 (Associated Press, 2023). About 10 days earlier, tourists in Rome were reported to have visited the city's sights in 43° C weather.

Global circulation models and IPCC reports issued over the last two decades have warned that climate change is likely to bring more frequent, hotter, and longer heat waves in temperate areas of the world (IPCC, 2021; Christidis et al., 2014). The nature of heat waves has changed in recent years (Pascal et al., 2021; Neethu and Ramesh, 2023), and excessive heat is often simultaneously experienced over very large geographical areas, which has led to the increasing use of the expression "heat dome" to describe them (NOAA, 2023; Wang et al., 2015).

In addition to causing loss of productivity and hence economic losses (Garcia-Leon et al., 2021; Zhao et al., 2021), very hot weather has been linked with adverse health effects (and their costs) and with excess mortality, i.e., with raising the fatality rate above what is considered normal for the time of the year at a certain location (Botzen et al., 2019; Bressler et al., 2021; Health Canada, 2011; Gasparrini et al., 2017; Arbuthnott and Hajat, 2017; Saha et al., 2014; and Qiao et al., 2015).

Numerous cities all over the world have developed and implemented plans to address the health threats posed by excessive heat. These plans (heat health watch/warning and response programs, or HHWRs) rely on advance weather forecast, issue alerts to the population ahead of and during excessive heat episodes, and enact a combination of public measures and volunteer activities to reach vulnerable members of the population, keep people out of the heat, and administer medical assistance if needed. They are generally triggered when the temperature is expected to exceed a certain threshold, taking into account humidity, other meteorological factors, the age and health status of the population, the building stock (whether or not insulated and air-conditioned) and whether the area is likely to suffer from the urban heat island effect (Ebi et al., 2004; Chiabai et al., 2018).

Despite their widespread adoption, with the exceptions of Ebi et al. (2004), Menne and Mathies (2009), ONERC (2009), US EPA (2015), Hunt et al. (2017), Chiabai et al. (2018), and Williams et al. (2022), relatively little assessment work has been completed to date to estimate their benefits and costs, or the cost-effectiveness with which health risks reductions are attained. This work generally relies on estimating the reduction in adverse health outcomes attributable to the program and attaching a monetized value to such a reduction.

One important element of such evaluations is whether alerts and health advice reach those that are most likely to be affected by the heat, and whether these persons abide by the behavioral modifications and precautions recommended by the experts. One such group is the elderly. Compromised fitness and health, certain medications, and a diminished perception of heat and thirst make the elderly a vulnerable group during heat waves—for physiological reasons. Social isolation makes it difficult for (life-saving) news and information to reach their targets, and concern that using cooling devices will run up the electricity bills may prevent protective behaviors among the poor (Klinenberg, 2003; Sheridan, 2007). Kalkstein and Sheridan (2007) and Sheridan (2007) conduct surveys in various US cities, finding that very few among the elderly change their behavior during hot days. In Europe, Pascal (2021) likewise reports that risk perception remains limited among the population and stakeholders. Laaidi et al. (2019) find that 88% of the population do not feel at risk during heat waves; only 4% of those aged 65 and older feel at risk. This may be due to the fact that many among the elderly do not perceive themselves as such (Taylor et al., 2009).

The purpose of this paper is three-fold. First, we wish to find out *if* people value public heat wave watch and response programs—and how much. Economic theory suggests that people more at risk should be willing to pay more; at the same time people might be willing to pay less, or nothing at all, for a public program if they consider private protection (e.g., using air conditioning, staying out of the heat) sufficient, cheaper and/or more effective. Our approach is different than that in Ebi et al. (2004) and Chiabai et al. (2018), in that we ask individuals from the general population of two countries, Spain and the U.K., to report information about their willingness to pay (WTP) for such programs.

Second, given the evidence that some individuals at risk may not recognize themselves as such, we wish to find out how people assess their own excessive heat health risks, before and after being informed about them. We also wish to see if their baseline assessment of their own risk and any revisions to it based on the provision of information influence their WTP for heat watch and response programs.

Third and last, what is the WTP per unit of mortality risk reduction—also known as the Value per Statistical Life (VSL)? Does the public compares excessive heat mortality risks to any other mortality risk? In the US, the VSL used in policy analyses generally comes from compensating wage studies that examine the tradeoffs that workers make between pay and workplace accident risks (Viscusi, 1993, 2013, US DHHS, 2016, US DOT, 2016). In the UK, they generally come from stated preference studies about transportation risks, derived from Carthy et al. (1999) (HM Treasury 2018) and recently reviewed by Chilton et al. (2020). Whether it is appropriate to apply them to environmental and public health programs is the subject of considerable debate in academic and policy circles, as what one is prepared to pay for a mortality risk reduction may well depend on the characteristics of the risk as well as the characteristics of the individual (Alberini, 2019).

We survey members of the general public in Spain and the U.K. and elicit information about their WTP for HHWRs that reduce health risks. These two countries were selected because global circulation models and predictions of excessive heat mortality generally distinguish between Southern and Northern Europe (Forzieri et al., 2017). The survey questionnaires were identical—except for the language, the national population figures shown to the respondent, and the absolute mortality figures in the two countries.

Respondents were assigned to one of two possible versions of the survey that differed for the format in which such mortality risks and risk reduced by the HHWRs were presented. In one, respondents were told about the expected number of fatalities in each of the next 10 years if nothing is done, and if heat response programs are implemented. Respondents were also told about the overall population, but we did not calculate risk rates for them. In the other, we provided the same information plus the implied mortality rates (expressed as X in 100,000 a year).

Respondents were further asked to choose between public program that save lives in the context of heat waves v. other causes of death, until an indifference point was reached that lets us infer whether a life saved in the health wave context is more, less or just as highly valued as another life saved.[1] This information can be combined with existing VSL figures to arrive at a

[1] Choice tasks where respondents must choose between life-saving programs are a simple example of person tradeoffs (also termed "equivalence of numbers")—one way of eliciting the value of health states to society or groups in the population that may or may not include the respondent (Pinto Prades, 1997). The goal is to find out how many cases cured of illness B or lives saved by program B are equivalent to one case cured from illness A or one life saved by program A. This rate of equivalence can be elicited directly by asking respondents to engage in matching tasks, or can be inferred from the responses to choice questions. Dalafave and Viscusi (2021) contrast prevented fatalities in shooting attacks with prevented fatalities in terrorist attacks. In examples from medical

VSL suited for the heat wave context, which in turn can be compared with our own direct estimates of the VSL.

Briefly, we find that people *are* willing to pay for heat watch and response program, especially among those persons who consider themselves at high risk and/or “upgraded” their risks to “very high” after receiving information about the possible adverse health effects of very hot weather. The implied VSL ranges between € 1.148 million and € 4.752 million (2019 PPP euro), for an average of about € 1.6 million. Our respondents valued heat wave mortality risk no less than general cardiovascular and respiratory mortality risks, just about the same as a cancer death, and more than road-traffic accident fatalities. Public heat wave response programs and private opportunities for defensive behavior are viewed as complements, rather than substitutes.

2. Materials

2.1 Survey Questionnaire

Our survey questionnaire is comprised of 6 sections. Section 1 collects basic information about the current health status of the respondents, the respondent’s experience with heat in the summer of 2019 (Konisky et al., 2015; Gärtner and Schoen, 2021), and the availability of air conditioning or other cooling devices at home and work. Section 2 asks respondents to identify possible consequences of excessively hot weather and indicate which, out of a list of groups (e.g., the elderly, children, the homeless, etc.), should be considered at risk during heat waves (Laranjera et al., 2021). At this point the respondents should have been focused enough on the

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decisionmaking and public health, the programs may target patients with disease of different severity (Nord, 1994), different age groups (Cropper et al., 1994), or be implemented at different point in time in the future (Cropper et al., 1994). More complex variants of person tradeoff questions may incorporate probabilistic descriptions of the accomplishments of the programs, allowing the analyst to study whether risk aversion applies to health states (Kemel and Paraschiv, 2018).

health risks associated with excessively hot weather, so we asked them if they considered themselves at higher, lower or roughly the same risk as the average person.

This exercise was followed by section 3, which provided information about the physiological effects of excessive heat (e.g., heat stroke, dehydration, heart failure, kidney failure, and death; see Gronlund et al., 2016) and a list of vulnerable groups, such as the elderly, children, people in compromised health, the homeless, people that work outdoors, etc. The respondents were then asked to re-evaluate their own risk level compared to others.

Section 4 of the questionnaire contained the valuation scenario. First we presented the respondents with a forecast of the mortality risks associated with hot weather in the next 10 years, based on global circulation models and the expected warming trends. Heat wave watch/warning and response programs would reduce these risks by a specified extent (see section 2.2 below), primarily by alerting the population, organizing community watch systems, operating cooling centers, extending swimming pool hours, distributing cooling devices, staffing emergency rooms and hospitals, and rescheduling work to cooler times or days.

Information about the respondent's WTP was elicited through double-bounded dichotomous choice questions. Respondents were assigned at random to one of four possible bid amounts (corresponding to € 10, € 25, € 53 and € 106 2019 PPP euro), which they would have to pay (if the programs were adopted) for each of the next 10 years.[2] The followup amounts were

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[2] Dichotomous choice contingent valuation questions are often cast as a vote in a hypothetical referendum. If a majority of the voters were in favor, survey participants are told, the program would be adopted and the taxpayers would be obliged to pay the stated amount in the form of a tax. This phrasing ensures incentive compatibility (Carson and Groves, 2007; Johnston et al., 2017), which may be compromised when the initial vote is followed by another vote with a revised cost amount (Watson and Ryan, 2007). We chose to avoid any reference to a referendum on the ballot in our survey, since in both the UK and Spain referenda are generally reserved to serious constitutional matters and laws—and clearly heat wave adaptation programs do not qualify as such. (For example, in 2017 a referendum was held in Catalonia to decide on whether the region should become independent. The referendum, which was accompanied by severe disruptions, was ruled unconstitutional. In 2016, a referendum was held in the UK to decide whether the country should remain in the European Union or leave it.)

twice as much (half as much), depending on whether the respondent was (was not) prepared to pay the initial "bid."

Section 5 of the questionnaire contained person tradeoff questions, which sought to see if the public views heat wave mortality risks as equivalent to mortality risks in other settings (see section 2.3 below). The questionnaire concluded with the usual sociodemographics (section 6).

2.2 Mortality Risks and Risk Reductions

Our valuation scenario was explicit about the fact that excessive heat increases mortality risks, and that risks can be significantly reduced through public health measures. We experimented with two alternate presentations of the baseline risks and risk reductions, and matched them with the appropriate graphs (Ancker et al., 2006).

Specifically, respondents were assigned at random to one of two possible variants of the questionnaire. In the first ("raw fatalities" version), they were told that forecasts indicate that in each of the next 10 years—from 2020 to 2029—there would be 2295 fatalities in Spain (3281 in the UK) attributable to the heat. The mortality attributed to other causes of death (e.g., cancer or cardiovascular illnesses) was also conveyed to the respondents for comparison purposes. The respondents were told what the projected population size was for that period, but we did not calculate the mortality rates (in heat waves or for other causes of death) for them.

The respondents were then told that government policies would be able to reduce this number by FILL2. The number FILL2 was selected at random out of four possible values (459, 918, 1377, 1836 for Spain; 656, 1312, 1969, and 2625 for the UK), which correspond to 20%, 40%, 60% and 80% reductions from the baseline. Would the respondent be willing to pay € X, where X was varied across the respondent, for such a reduction?

In the second version of the questionnaire (the "rates" version), respondents were shown exactly the same information—except that this time the population rate was computed for them. In Spain, for example, the respondents were told that 2295 fatalities mean 5 fatalities for every 100,000 people. When told about the reduction in the number of fatalities, respondents were also informed that this reduction would bring the fatality rates from 5 in 100,000 to 4 in 100,000, 3 in 100,000, 2 in 100,000 and 1 in 100,000, respectively, corresponding to 20%, 40%, 60% and 80% risk reductions. The study design is summarized in table 1. In both variants of the questionnaire, respondents are randomly assigned to initial bids selected at random out of a prespecified array.[3]

The graphs used to convey the magnitude of the risks are displayed in figures 1 and 2, respectively. Figure 1 shows that, in the "raw fatalities" version of the questionnaire, respondents were informed about the total fatalities attributable to the heat and to other causes of death. Figure 2 displays the corresponding graph for the "risk rates" version of the questionnaire. This second graph also includes a "risk ladder," where the magnitude of the risks are translated into a "community equivalent" meant to be salient to the respondent.

We note that our questionnaire did not provide forecasts of the number of hospitalizations or minor illnesses with and without the program, as it has been our experience (Alberini et al., 2012) that such figures get trumped by the mortality information.

2.3 Life-saving Program Tradeoffs

Right after the valuation portion of the questionnaire, the respondents faced a series of choice tasks about life-saving programs. They were to tell us which they would prefer between two programs that cost the same amount of money—Program A, which saves 100 lives during

[3] This array is { 10, 20, 50, 100 } Euro for Spain and its 2019 PPP equivalent for the UK, namely { 10, 25, 55, 110 } GBP. These values were selected because they cover a broad range of implied VSL figures—from 200,000 to 10 million euro. When converted to 2019 PPP euro, both arrays are equivalent to 10, 25, 53, and 106 2019 PPP euro.

heat waves, or Program B, which avoids 100 fatalities from a specified cause of death. This latter cause of death was selected at random from cancer, cardiovascular causes, or road-traffic accidents. Respondents were offered three possible responses options: Program A, Program B, or "indifferent between the two."

No further questioning followed if the respondent chose the "indifferent" option. If program A (program B) was chosen, then in the next question program A still saved 100 lives in the heat wave context whereas program B was to save X lives, with X greater than 100 (less than 100). The subsequent choice questions adjusted the follow-up number of lives saved by Program B (holding the lives saved by program A fixed at 100) to arrive at or close to indifference between the two programs. Approximately half of the respondents were assigned at random to a variant of this procedure that iteratively changed the number of lives saved by program A—the heat wave program—while holding the lives saved by program B fixed at 100.[4]

2.4 Survey Administration

The survey was administered from the end of September to late October 2019 in Spain and the UK. The data collection was coordinated by European National Panel s.r.o. Czech Republic. The survey questionnaire was self-administered by the respondents online, with the respondents themselves recruited from internet consumer panels.

We used quota sampling with quotas for education (three categories), age (three categories), city or town size (three categories), gender, and region. Participation was restricted

[4] These questions can be compared with the risk-risk tradeoffs in Mussio et al. (2023), where respondents are asked at which out of two locations they would prefer to live. The two locations differ in terms of traffic accidents and extreme weather events mortality risks, and can be compared with the risk in the area where the respondent lives.

to respondents aged 18-65.[5] Our final sample sizes are 1,469 completed interviews in Spain and 1,903 in the UK. Table 2.A summarizes the two samples.

3. Methods

3.1 Theoretical Model

A household production model that accommodates a wide range of public program and private behavior posits that individual derive utility from consumption and disutility from illness (or the risk of dying), and that adverse health effects can be abated by the public program and by private protection behaviors:

(1) $$U(X, S(P, A(P))$$

where X denotes consumption, S captures any adverse health effects or the risk of such effects, P is the public policy that seeks to reduce the adverse health effects of heat waves, and A protection behavior, which may itself depend on the level of the policy. The budget constraint states that income must be spent on either consumption or on the private protection measures, i.e., $y = X + P_A \cdot A$, where we normalize the price per unit of consumption to one.

How much is the consumer willing to pay for a small change in P? On plugging the budget constraint into utility function (1), taking the total differential with respect to income *y* and public program P, and re-arranging, we obtain the marginal WTP:

(2) $$\frac{dy}{dP} = (U'_S/U'_X) \cdot \left(\frac{\partial S}{\partial P} + \frac{\partial S}{\partial A} \cdot \frac{\partial A}{\partial P}\right),$$

where U'_S and U'_X denote the marginal disutility of the adverse health endpoints and the marginal utility of income, respectively. The right-hand side of (2) is negative, indicating that people are prepared to pay for the program, if the public program and private behaviors are effective at

[5] Although persons older than 65 are considered a vulnerable group during excessive heat episodes, the survey company could not guarantee representativeness among their panelists aged 66 and older.

reducing the adverse health effects ($\partial S/\partial P < 0$ and $\partial S/\partial A < 0$) and the public program and the private behaviors are complements ($\partial A/\partial P > 0$). If a consumer views private protective behaviors as substitutes for the public program ($\partial A/\partial P < 0$), the term in the second parenthesis may become smaller in absolute value or even zero (indicating a lower or zero WTP). A low WTP would also be expected if someone believes that the program has only limited effectiveness, making $\partial S/\partial P$ smaller in absolute value, or even zero.

3.2 Econometric Model of WTP

Double-bounded elicitation brackets an interval in which someone's WTP falls. We assume that the underlying WTP is normally distributed around the expected value $\mathbf{x}_i\boldsymbol{\beta}$, and fit the log likelihood function

(3) $$ln\mathcal{L} = \sum_i^n \ln\left[\Phi\left(\frac{H-\mathbf{x}_i\boldsymbol{\beta}}{\sigma}\right) - \Phi\left(\frac{L-\mathbf{x}_i\boldsymbol{\beta}}{\sigma}\right)\right]$$

where H and L denote the upper and lower bound of the interval where the respondent's exact WTP falls, σ is the standard deviation of the WTP, and $\Phi(\cdot)$ denotes the standard normal cdf (see Alberini, 1995).

Vector $\mathbf{x}_i$ includes income, education, other sociodemographics, and, based on section 3.1, variables that capture the respondent's opportunity for protective behavior (e.g., availability of air conditioning), concern about the seriousness of the health effects of excessive heat, and trust in the effectiveness of the public program. One important factor is whether the respondent considers himself or herself at high risk—before and after the provision of information about excessive heat in the questionnaire. We are also interested in whether residents of urbanized areas, value, all else the same, heat wave watch/warning and response programs more highly than residents of rural areas. Finally, we wish to assess whether there are systematic differences across the two countries—controlling for income, education, and other characteristics of the respondents—and whether the presentation of the risks (i.e., the "raw figures" v. "rates" treatment) affects the WTP.

3.3 Determinants of Risk Upgrades

In light of the results from earlier studies—that people at high risk often do not perceive themselves as such and thus potentially fail to engage in protective behaviors—it is of independent interest to examine what types of individuals "upgrade" themselves to being at high risk in the event of excessively hot weather after reading the relevant information.

For this purpose, we fit probit models where we let the likelihood of such "upgrades" depend on the current health status of the respondents—measured via a simple rating on a five-point scale or by the presence or absence of specific health conditions. Income, education, and other sociodemographics are also included.

3.4 Estimating the VSL

If the reduction in heat mortality risks is the only effect of the public program in our survey (i.e., respondents did not consider reductions in minor illnesses or hospitalizations), it is possible to use the WTP for the program to compute the implied Value per Statistical Life (VSL). The VSL is defined as the WTP for a marginal risk reduction, or alternatively as the total WTP held by a population of size N for a uniform reduction of 1/N in everyone's risk of dying (Alberini, 2019).

First, we assume that the WTP is proportional to the size of the risk reduction:

(4) $$WTP_i^* = \delta \cdot \Delta R_i + \varepsilon_i,$$

where δ is the VSL, and fit an interval data model similar to that in (3), but with $\mathbf{x_i \beta}$ replaced by $\delta \cdot \Delta R_i$. A simple amendment of equation (4) lets us check whether the VSL varies across the two countries or is affected by the presentation of the risks and risk reductions (RATE dummy):

(5) $$WTP_i^* = \Delta R_i(\delta_1 + \delta_2 \cdot SPAIN + \delta_3 \cdot RATE) + \varepsilon_i.$$

Equations (4) and (5) assume perfect proportionality of the WTP to the size of the risk reduction. We check whether such an assumption is borne out in data by separating the WTP into four different groups—that for the 1 in 100,000 risk reduction, that for the 2 in 100,000 risk reduction, etc.—and compute the VSL in each group by dividing the mean WTP by the risk reduction.

3.5. Person-tradeoff Evidence

We assume that in the program choice portion of the questionnaire, respondents choose program A if

(6) $$\alpha_A L_A > \alpha_B L_B,$$

where L_A and L_B are the lives saved by program A and program B, respectively, and the αs can be thought of as either the monetized value or the marginal utility of avoiding one fatality. This implies that $\alpha_A/\alpha_B > L_B/L_A$. If the respondent is indifferent between A and B, then α_A/α_B is equal to L_B/L_A.

We use the sequence of choice questions to obtain the exact value of α_A/α_B (when respondent say they are indifferent) or to bracket as narrow as possible an interval around it. We assume that α_A/α_B is normally distributed, and estimate a continuous-/interval-data model, obtaining three "alpha" ratios—for heat waves v. each of three specific causes of death (cancer, cardiovascular illness, road-traffic accidents).

We test if each "alpha" ratio is equal to one (implying equivalence of one life saved, regardless of the context) using a Wald test. The Wald statistic is computed as $(\hat{\alpha}_j - 1)^2 / Var(\hat{\alpha}_j)$, where j=1, 2, 3 and $Var(\hat{\alpha}_j)$ is the asymptotic variance of $\hat{\alpha}_j$. For large sample size and under the null, the statistic is distributed as a chi square with one degree of freedom.

4. The Data

Descriptive statistics of the two samples are displayed in table 2.B. As per our sampling frame, gender representation was approximately even in each of the two samples. Household size is slightly larger for the Spain respondents, whereas the UK respondents are more inclined to report their household income, are slightly wealthier, and somewhat more highly educated.

Figure 3 shows that the Spain sample appears to be more aware of the potentially lethal effects of excessively hot weather (70% v. 56%), and both samples promptly identify the elderly as a vulnerable category (95% and 86% of the Spain and UK samples, respectively). Both samples ascribe the same level of vulnerability to children and the homeless, which is higher than that associated with the poor. The two samples diverge when it comes to assessing persons living in the city v. residents of the countryside. The latter are considered at higher risk than the former by the Spain respondents, while the converse is true for the UK sample.

Table 2.C displays the shares of the respondents that consider themselves at higher-than-average health risk in the event of a heat wave. These shares are virtually the same across the Spain and UK samples both before and after the provision of information about the health effects of heat waves. In both samples, the shares that consider themselves at higher than average risk *increase* after medical and public health information is provided in the questionnaire.

Table 2.D displays the respondents' rating of their health status and the presence of certain health conditions. Table 2.E summarizes heat risk perceptions and the respondents' assessment of the likely effectiveness of the programs. The shares of respondents that find heat-related illnesses "very painful" and the health risks from heat waves "scary" range between 12%, and 24%, suggesting relatively low to moderate dread for heat wave morbidity and mortality effects.[6]

As shown in figure 4, while a majority of the Spain sample has heard of excessive heat alerts in their own city or town (40% elsewhere), no more than 30% of the UK respondents has heard of excessive heat alerts—locally or elsewhere. Both samples are relatively unfamiliar with cooling centers.

In spite of this, at least 60% of the Spain respondents and 65% of the UK respondents would pay for the implementation of heat wave policies. About 55% of the Spain respondents and 45% of the UK respondents treated one life saved in the heat wave context as equivalent to one life saved from other causes of deaths.[7] There is little evidence of extremely high equivalence numbers: Only about 4% of the respondents indicated that the considered one life saved from heat waves equivalent to 4 or more lives saved from other causes of death.

5. Results

5.1 WTP for the Program

Our respondents *are* willing to pay for health watch and response programs: Based on the responses to the first dichotomous choice question, 63.69% were willing to pay at least € 10/year, 57.49% € 25/year, 48.98% € 53/year, and 41.82% were willing to pay € 106/year. We

[6] For comparison, Alberini and Ščasný (2018, 2021a) find that cancer is "highly dreaded" by 50-60% of the subjects in several countries of the European Union.
[7] In other words, they opted for the "indifferent" response in the very first question about the programs.

combine the responses to the initial and followup bids, and fit the interval-data model of equation (3), which estimates the mean and median WTP for the heat wave programs to be almost € 50 (2019 PPP euro) for each of ten years. The WTP is unaffected by the presentation of risk, and is € 8 lower among the Spanish respondents, but this difference is statistically significant only at the 10% level (table 3).[8]

As shown in table 4, however, once we control for respondent sociodemographics, this latter effect is reversed, as the Spanish subjects are, all else the same, willing to pay almost € 8 more. Again, this difference is statistically significant only at the 10% level (specifications (A) and (B)), and vanishes when we control for own risk perceptions, opportunities for own protective behavior, urban v. rural residence, and additional attitudes towards heat wave risks and policies (specifications (C)-(E)).

The specifications of table 4 further show that the risk presentation device (i.e., the "rates" v. absolute mortality version of the questionnaire) had no effect on the WTP, and that the WTP grows with income and (weakly monotonically) with education. The income elasticity of the WTP is, at the average household income, 0.4382. The WTP does not depend on gender, family status, or the number of elderly persons or children in the respondent's household, although it does grow weakly with the size of the household.

By contrast, own risk perceptions are strong determinants of the WTP for the program: Persons who believe themselves at average risk are willing to pay € 13 to € 15 more than those who consider themselves at lower than average risk, those who think of themselves as high risk €

[8] These results are based on assuming that the underlying WTP is normally distributed. We also use the combined responses to the first and follow-up WTP question to construct a non-parametric, Kaplan-Meier estimator of the survival function of the WTP in each country. Figure A.1 in the Appendix shows that the two countries' survival functions (the percentage of the sample willing to pay any given amount) are well-behaved and for the most part overlapping. A log-rank test of the null that the distributions in the two countries are identical however rejects the null at the 1% significance level (log-rank statistic 65.97, for a p value of less than 0.001). This finding essentially confirms that, when we do not control for covariates, the WTP tends to be different across the samples from the countries.

26- € 32 more, and those who upgraded their risk to "very high" after they read the informational sheet about the heath effects of heat waves an additional € 20 - € 25 more per year.

We had wondered whether persons who have the means to protect themselves from excessive heat might be willing to pay less for a public program, but the coefficients on having air conditioning at home and work, respectively, are positive and statistically significant. Either persons who highly value protection from the adverse effects of heat have installed air conditioning (Bélanger et al., 2015), or subjects with access to air conditioning understand it to be a complement rather than a substitute for the public health programs—or both. Finally, the WTP is higher, as expected, when someone fears heat wave illness risks and, importantly, when they consider the proposed policy effective.

All in all, the WTP depends in predictable ways on the factors identified by economic theory, own risk, measures of the seriousness of heat-related illness and perceived policy effectiveness (Huber et al., 2020): We conclude that it meets interval validity criteria.

5.2 Own Risk Upgrades

Those subjects who upgraded their own risk to "very high" are willing to pay for the program more than the others. We wish to examine their characteristics. Table 5 displays the results of probit regressions that relate upgrading one's risk to "very high" to the health status of the respondent and his or her sociodemographics. We measure the health status in two ways—using the respondent's own rating on a five-point scale from excellent to poor (specification (A)), and by entering dummies for the presence of health-professional diagnosed conditions (specification (B)).

Both specifications consistently point to the fact that risk upgrades are much more likely among those who considered themselves in poor health, and/or report having high blood pressure or high cholesterol (the two most important causes of heart disease), being diabetic (which raises kidney disease and kidney failure risks), and/or having COPD.[9]

It is interesting that subjects who have air conditioning at home are more likely to upgrade themselves to "high risk." Risk upgrades are less likely among highly educated people, are unaffected by income, being part of the Spanish or British sample, and the mortality risk presentation device.[10]

A respondent with the average income in the sample, with high school education, with air conditioning at home and in "excellent health" has a 10% chance of upgrading their risk. This probability doubles, jumping to 21%, if this person said they were in "poor health." Based on specification (B) in table 5, if this person reported no health conditions, his or her chance of upgrading to "high risk" would be 6.61%. Having the two cardiovascular conditions raises this chance to 68%, being diabetic to 31%, and suffering from COPD to 31%.

5.3 The VSL

Table 6 reports the results of interval-data regressions that relate the WTP to the mortality risk reduction delivered by the program. The coefficient on the risk reduction should be interpreted as the VSL (in thou. PPP euro), *if* the respondents accepted that the only consequence of the program was the mortality risk reduction and *if* the WTP is proportional to the size of the risk reduction. The VSL is thus estimated to be € 1.623 million (2019 PPP euro). The estimate of

[9] Further adding age and age squared to the probit regressions results in insignificant coefficients on these variables. We likewise obtain insignificant coefficients on age and age squared if we strip the model of most regressors, only keeping the Spain dummy, the risk "rates" version of the questionnaire dummy, age and age squared.

[10] The risk presentation treatment came later in the survey questionnaire, so it shouldn't have had an effect on the risk "upgrade" decisions—and it didn't.

the VSL does not change significantly across Spanish and British respondents or with the mode of presentation of the mortality risks.

Figure 5 presents VSL figures estimated using a somewhat different approach. We fit the interval data model of the WTP with no covariates to each of the subsamples that were assigned to the 1 in 100,000, 2 in 100,000 etc. risk reductions, and obtain the VSL as the mean WTP for that subsample divided by the mortality risk reduction assigned to that subsample. The results from this approach are striking: the VSL is € 4.752 million (2019 PPP euro) among those respondents that received the 1 in 100,000 risk reduction, but falls with the size of the risk reduction to € 1.148 million in the group that valued the 4 in 100,000 risk reduction. This phenomenon is well documented in the literature that has sought to obtain estimates of the VSL using stated preferences (see, for example, Alberini and Chiabai, 2007; Chestnut et al., 2012).

5.4 Program Tradeoffs

The responses to the program tradeoff questions indicate that an avoided excessive heat fatality is on average deemed equivalent to almost 1.5 avoided road-traffic accident fatalities,[11] possibly because of the stronger degree of personal responsibility and behavioral choices associated with road traffic accidents (Alberini and Ščasný, 2011). One avoided fatality in the heat wave context is considered equivalent to one avoided cancer fatality. Technically speaking, the ratio of the respective marginal utilities or VSLs is 0.91, but a Wald test does not reject the null that the ratio is one.[12]

Finally, one life saved in the heat wave context is held equivalent to 1.27 lives saved from cardiovascular causes of death. The standard error around this estimate is 0.0762, and the

[11] The exact estimate is 1.4866 (s.e. 0.0852). The Wald test of the null that this coefficient is equal to one is 32.59, for a p-value less than 0.001.
[12] The exact estimate is 0.9191 (s.e. 0.0705), and the Wald statistic Is 1.63 (p-value 0.2033).

Wald test of the null that this "alpha" ratio is equal to one is 12.55 for a p-value of 0.004. The null is thus rejected at the conventional significance levels, in spite of the fact that the cause of many fatalities during heat waves *are* cardiovascular problems.

6. Discussion

Our survey allows us to estimate the VSL in the heat wave context in two ways. First, *if* we assume that the mortality risk reductions depicted in the valuation scenarios were the only health risk reductions people associated with the program, the VSL implied by our subjects' WTP responses ranges between € 1.148 million and € 4.752 million (2019 PPP euro).

These values can be compared with those adopted by the UK government in its policy analyses (1.6 million 2010 British Pounds; HM Treasury, 2018), with estimates from compensating wage studies conducted in these two countries (Martinez Perez and Mendez Martinez, 2009 for Spain, Arabsheibani and Marin, 2000 for the UK[13]), and with the VSL recommended by OECD for environmental and transportation safety policy analysis (3.6 million 2005 USD). They are similar to several figures from Italy in Alberini and Chiabai (2007), namely those for 30-49-year-olds in good health (1.061-6.211 million 2019 PPP euro), and from the Czech Republic in Ščasný and Alberini (2012) (2.4 million 2010 PPP euro). While the Alberini and Chiabai study inquired about reductions in cardiovascular and respiratory mortality risks of any origin, Ščasný and Alberini (2012) focused on several causes of death attributable to climate change.

[13] Using labor market data, Martinez Perez and Mendez Martinez arrive at a VSL for Spain between €2.8 and €8.3 million (Martinez Perez and Mendez Martinez, 2009). For the UK, Arabsheibani and Marin (2000) report a VSL of several million, whereas Hintermann et al. (2010), using panel data, find no evidence that compensating wage differentials even exist. This discrepancy may be due to the fact that it is extremely difficult to disentangle econometrically the determinants of workers' wages (Alberini, 2019).

Second, our respondents engaged in person tradeoffs that asked them to choose between different live-saving programs. Variants on this type of questions are sometimes deployed in medical decisionmaking and health policy research (Robinson et al., 2017). The equivalence rates elicited through this exercse could be combined with existing estimates of the VSL to predict or validate the VSL in the desired context. To illustrate, Sanchez-Martinez et al. (2018) report VSL of € 1.3 to € 1.7 million in the transportation accident context. These figures are based on a 2009 survey. Converted to 2019 PPP euro, they are equivalent to € 1.534 – € 2.005 million (2019 PPP euro). When multiplied by the equivalence rate between heat wave fatalities and road-traffic accident fatalities from our survey, these figures become € 2.301 million and € 3.007 million (2019 PPP euro), which fall within the range of VSL figures obtained directly from the respondent's WTP for the HHWR programs in our survey.

For comparison, the FUND model (Anthoff and Tol, 2010) values extreme weather fatalities at 200 times the GDP per capita of the country where the fatalities occur (Cline, 1992). Based on this assumption, and using for simplicity the most recent GDP per capita figures made available by international organizations, each prevented extreme weather fatality would be worth \$29,554×200=\$5.911 million in Spain, and \$ 43,070×200=\$8.664 million in the UK (current US\$).[14] These values clearly exceed even the largest VSL estimates from our survey, namely VSL is € 4.166 million (2019 PPP euro) for Spain, and € 5.350 million (2019 PPP euro) for the UK.

Many government agencies and international organizations currently perform income-adjusted benefit transfers that rely on a VSL income elasticity equals to one (e.g., US Department of Transportation, 2016; Viscusi and Masterman, 2017). In many instances, however, the income elasticity of the VSL has been estimated to be less than one. This is the case

[14] See https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.

in our survey, where the income elasticity is 0.4382. Alberini and Ščasný (2021a) find it to be 0.5 to 0.7, in line with Masterman and Viscusi (2018), at least for countries with sufficiently large VSL.

We use the results from our survey, combined with three possible values for the income elasticity (0.5, 0.7, 1.0, with 0.7 the central value and 0.5 the one closest to that estimated from our survey), plus information about household income by country from Eurostat (based on EU-SILC and the European Community Household Panel surveys, online data code ILC_DI04) to predict the VSL of each of the countries in the European Union plus Norway and Switzerland. Combined with predictions of the population and the heat wave mortality effects during the 2020-29 decade from the PESETA III project (Forzieri et al., 2017), for a total of about 32,182 lives lost attributable to heat waves a year during the 2020s, we arrive at total mortality damages of € 63.1 billion (when using a VSL income elasticity of 0.7), € 70.7 billion (income elasticity of 1.0) and € 59.0 billion euro (income elasticity of 0.5) (2019 PPP euro).[15] A 20% reduction in risk—one of the scenario that respondents were randomly assigned to—would thus yield benefits for € 12.6 billion (2019 PPP euro).

7. Conclusions

We have asked three research questions about the benefits of HHWRs and surveyed members of the general public aged 18-65 in Spain and the UK to elicit their WTP for such public health programs.

The answer to our first research question is that our survey participants *are* willing to pay for such programs. Their WTP responses are internally valid, in that the WTP grows with

[15] Forzieri et al (2017) predict the fatalities due to heat waves in Europe a year at 103,000 during the 2050s and 151,500 during the 2080s. These fatalities correspond to € 202 billion, and € 297 billion, respectively (2019 PPP euro, using an income elasticity at 0.7). See Alberini and Ščasný (2021b) for more details.

income, education, the perceived severity of the heat wave health risks and dread thereof, and the perceived effectiveness of the programs. It is also greater for persons who have access to air conditioning at home (or work), suggesting that either these persons view private protection (air conditioning) as a complement to the public programs, or that those who value excessive heat health risk reductions highly have already proactively installed air conditioning to protect themselves.

Second, we have found that persons what considered themselves at higher than average risk (prior to receiving our information about the health consequences of excessive heat) report higher WTP. About 9% of the respondents upgraded their risks to “very high risks” after reading the informational sheet in the questionnaire. These persons were primarily in poor health, had chronic conditions, and were comparatively less well educated than the others, which suggests that our text did provide some new information to subjects that were not previously fully aware of the health risks. “Upgrades” are associated with higher WTP. This evidence suggests that targeting messaging and education may increase awareness and promote protective behaviors among persons at high risk who do not (yet) perceive themselves as such (Kalkstein and Sheridan, 2007; Sheridan, 2007; Pascal, 2021, and Laidi et al., 2019).

One limitation of our study, however, is that we were only able to collect completed questionnares from persons aged 18-65, as the survey firm’s panel of consumers was not representative of the population aged 66 and older. Earlier studies (e.g., Taylor et al., 2009) have found that the elderly and the very elderly are reluctant to admit that they themselves (and not “other elderly people”) are at elevated risk during heat waves and to act accordingly.

Third, our survey provided with various opportunities to compute the VSL in the heat wave context. We deployed an experimental treatment, in that we told respondents what the expected number of heat-wave related fatalities would be if no program was implemented and with the program, but only about one-half of the respondents were also presented the corresponding risks and risks reductions, expressed as X in 100,000 per year. This experimental treatment was devised to investigate issues with absolute and relative risk reductions, which are sometimes observed when the questionnaire omits information about the size of the population (Baron, 1997; Johannesson et al. 1996). No difference in the WTP (and the VSL derived from it) was observed across the two subsamples of respondents, suggesting that people were processing the baseline risks and the risk reductions correctly, showing no signs of confusion between absolute and relative risk reduction once *all* of the relevant information was provided.

We have also elicited life-saved equivalences, which suggested that members of the general public consider one life saved in the heat wave context approximately equivalent to one life saved from cancer. Avoided excessive heat fatalities are considered slightly more important or valuable that avoided cardiovascular fatalities, which may at first blush seem surprising, since most of the heat wave fatalities *are* cardiovascular fatalities.

Perhaps the respondents became overly focused on heat waves as a result of taking part in a survey about heat waves. Alternatively, some may have considered a program that targets a very specific cause of death during a precise time of the year (the summer) more likely to be effective and thus more attractive. Respondents may have also reasoned that generic "cardiovascular deaths" are likely the result of genetics, lifestyle, exposure to pollution, and other causes, and may have questioned the effectiveness of a program that would potentially address so many diverse factors. At any rate, while this "overvaluation" is statistically significant, at a ratio of 1.27 we would judge it to be practically unimportant.

Statements and Declarations

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Figure 1. Graph used in the "raw fatalities" version of the questionnaire.

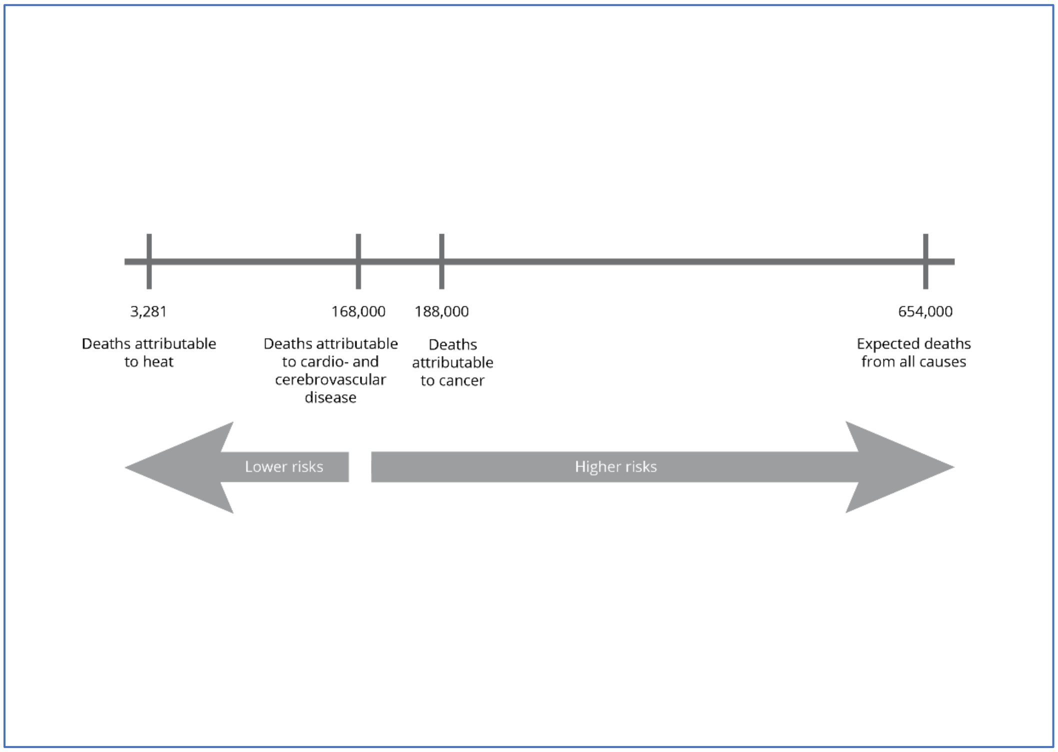


Figure 2. Graph used in the "risk rates" version of the questionnaire.

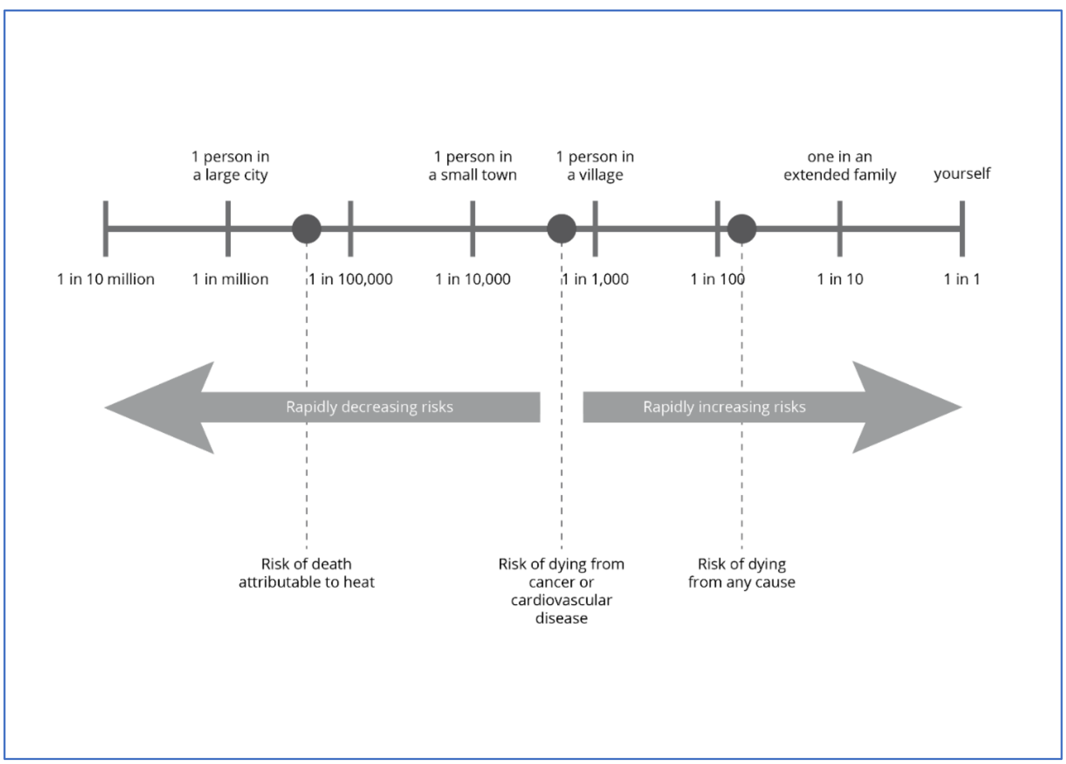


Figure 3. Respondent awareness of heat wave health risks and vulnerable populations.

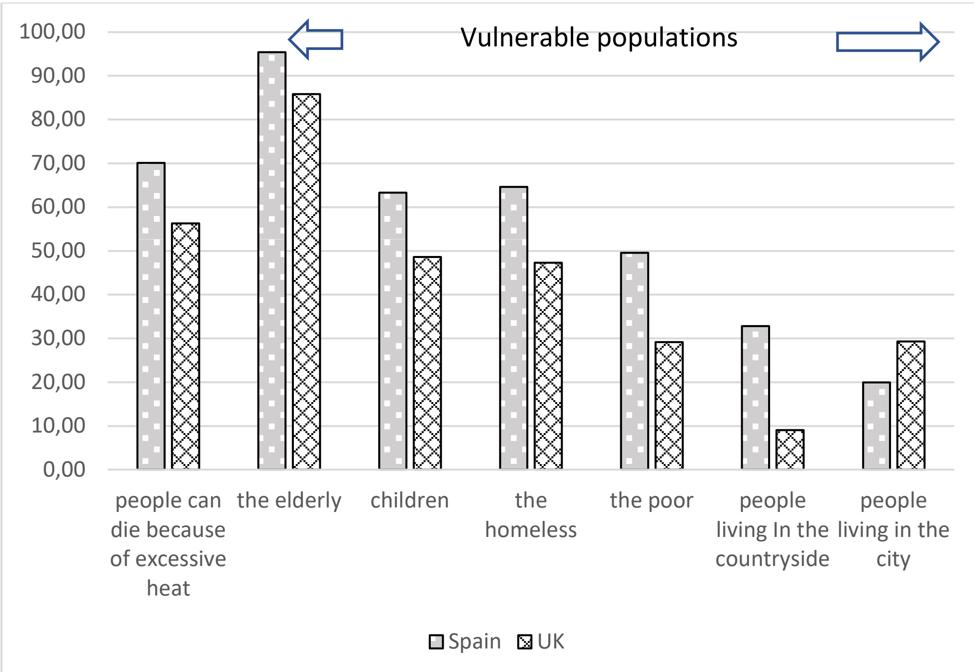


Figure 4. Awareness of policies.

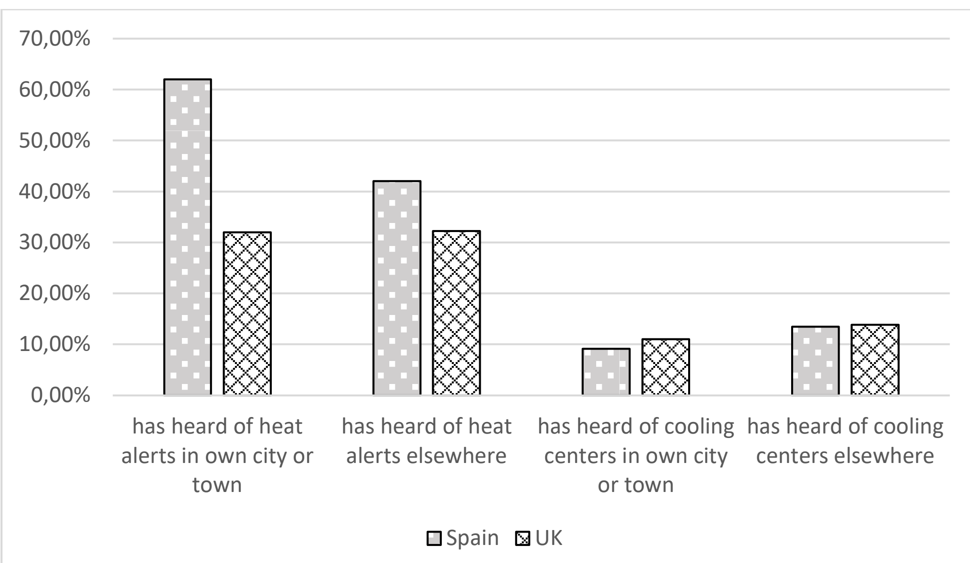


Figure 5. VSL estimated separately from the subsamples that were assigned the 1 in 100,000 to 4 in 100,000 risk reduction, assuming that the health risks reduced by the program are exclusively mortality risk reductions.

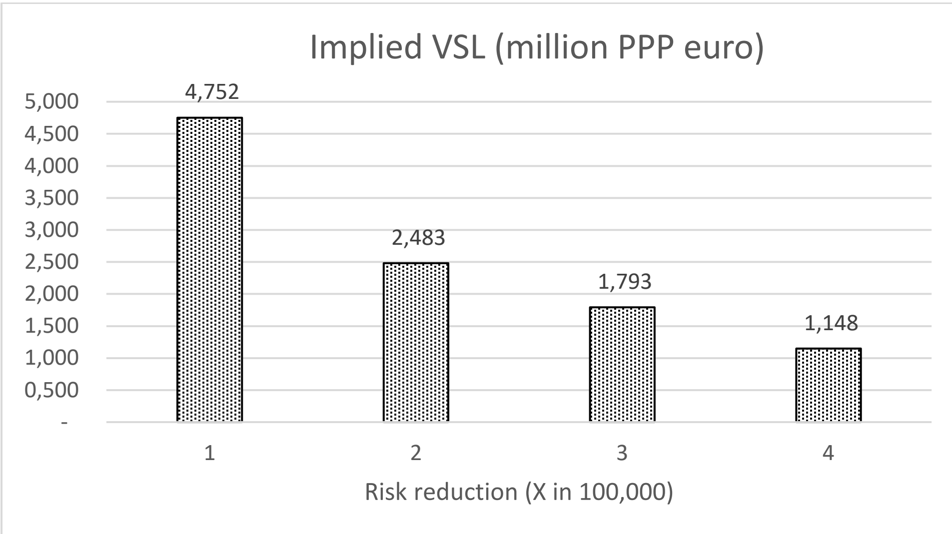


Table 1. Summary of the Design.

	FILL1: Percentage risk reduction and risk reduction expressed as a rate*							
	20% 1 in 100,000		40% 2 in 100,000		60% 3 in 100,000		80% 4 in 100,000	
	Reduction in fatalities	Final fatalities	Reduction in fatalities	Final fatalities	Reduction in fatalities	Final fatalities	Reduction in fatalities	Final fatalities
Spain (baseline=2295)	459	1836	918	1377	1377	918	1836	459
UK (baseline=3281)	656	2625	1312	1969	1969	1312	2625	656

* The baseline is 5 in 100,000.

Table 2. Summary of the samples. Number of respondents, percentage or sample average.

	Spain	UK
A.Study Design		
Completed questionnaires	1469	1903
"raw fatalities" version of the questionnaire	741	971
"rates" version of the questionnaire	728	932
B.Sociodemographic characteristics		
female	50.51%	50.47%
male	48.67%	49.45%
gender—prefer not to answer	0.82%	0.11%
household size	3.04	2.85
monthly net household income (2019 PPP euro)	1858.45	2403.86
income not reported	28.45%	13.56%
high school diploma	20.42%	16.61%
some college	8.03%	29.69%
college degree or better	28.45%	32.11%
Has air conditioning at home	49.35%	12.72%
Has air conditioning at work	48.74%	38.94%
C. Respondent self-assessment of high risk for the health consquences of heat waves		
High risk (ex ante, before provision of information)	9.38%	8.68%
High risk (ex post, after provision of information)	13.55%	13.62%
Upgrades to high risk after provision of information	9.26%	7.51%
D. Self-assessed health status of the respondent		
Excellent health	11.32%	1232%
Very good health	36.74%	38.13%
Good health	35.86%	29.81%
Fair health	11.32%	14.74%
Poor health	4.77%	5.00%
Has high blood pressure	18.92%	18.31%
Has high cholesterol	23.62%	12.56%
Has diabetes	5.65%	6.62%
Has COPD	16.34%	18.13%
E. Other perceptions of risks and policy effectiveness		
Respondent considers heat wave illnesses very scary	23.91%	19.26%
Respondent very scared of heat wave health risks	17.19%	11.56%
Respondent strongly agrees that policy is effective	20.18%	31.45%

Table 3. Interval data models of the WTP for the program.

	(A)	(B)
constant	49.2675*** (2.1186)	52.2416*** (3.4863)
Spain		-7.9304* (4.2688)
“rates” version of the questionnaire		0.9266 (4.2267)

Standard errors in parentheses; ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively,

Table 4. Interval data models of the WTP: Internal validity.

	(A)	(B)	(C)	(D)	(E)
constant	-2.4011 (7.8263)	-17.1572** (8.6778)	-17.9389** (8.6961)	-19.3324** (8.8672)	-28.6564*** (8.8531)
Spain	7.6925* (4.5659)	7.6584* (4.5609)	1.5665 (5.0137)	1.8395 (5.0241)	-0.0790 (5.0087)
“Rates” version	0.7101 (4.1653)	1.1997 (4.1564)	1.0207 (4.1493)	1.0047 (4.1488)	0.6219 (4.0838)
Monthly household income (2019 PPP euro)[a]	0.0115*** (0.0020)	0.0117*** (0.0020)	0.0105*** (0.0020)	0.0105*** (0.0020)	0.0107*** (0.0020)
Missing income	-12.6026* (6.7553)	-10.7033 (6.7476)	-12.8721* (6.7724)	-12.9549* (6.7728)	-11.2305* (6.6660)
Secondary educ A level	28.2834*** (6.3695)	30.1247*** (6.3710)	28.5987*** (6.3885)	28.2548*** (6.4012)	28.9032*** (6.3170)
Some college	22.1246*** (6.3037)	23.6752*** (6.3019)	22.6201*** (6.3218)	22.4120*** (6.3259)	23.9312*** (6.2480)
University degree or post-grad	35.4542*** (5.7275)	37.3127*** (5.7282)	35.0660*** (5.7809)	34.7389*** (5.7933)	35.6883*** (5.7419)
Female	-5.6054 (4.3212)	-5.2003 (4.3133)	-4.4203 (4.3128)	-4.0255 (4.3393)	-5.6297 (4.2735)
Household size	3.7694** (1.7542)	3.7010** (1.7534)	3.1952* (1.7574)	3.1785* (1.7574)	2.7236 (1.7315)
Has children	4.3079 (4.5959)	3.3677 (4.5965)	3.8569 (4.5974)	4.0755 (4.6045)	2.6394 (4.5297)
Number elderly	0.0823 (1.7100)	-0.0968 (1.7216)	-0.0561 (1.7239)	-0.1028 (1.7254)	-0.2348 (1.7234)
Same risk		13.2132*** (4.6736)	13.8496*** (4.6704)	13.8874*** (4.6703)	14.7982*** (4.5997)
Higher risk		32.2184*** (7.9785)	32.2116*** (7.9874)	32.2470*** (7.9872)	26.3301*** (7.9236)
Upgraded own risk		26.4007*** (7.8442)	25.2232*** (7.8453)	25.3740*** (7.8454)	19.0037** (7.7608)
AC at home			11.8686** (5.2058)	11.6178** (5.2140)	10.8251** (5.1421)
AC at work			10.1496** (4.3879)	9.8854** (4.3991)	10.0381** (4.3270)
Urban area resident				3.5106 (4.3046)	1.8720 (4.2403)
Heat wave illnesses painful					21.4827*** (5.5469)
Scared of heat wave risks					14.2385** (6.6780)
Policy is effective					27.0721*** (5.0994)

Standard errors in parentheses; ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. [a]: Recoded to zero if the respondent did not report income.

Table 5. Probit model of own risk upgrade to "very high."

	(A)	(B)
Intercept	-1.3257***	-1.5259***
	(0.1300)	(0.0981)
Health state: Very good	-0.3005***	
	(0.1037)	
Health state: Good	-0.1802*	
	(0.1047)	
Health state: Fair	0.1115	
	(0.1192)	
Health state: Poor	0.4655***	
	(0.1443)	
Monthly household income[a]	0.0000375	0.00002700
	0.0000282	0.0000279
Missing income dummy	-0.1106	-0.1086
	(0.1042)	(0.1035)
Secondary educ A-level	-0.2963***	-0.2825***
	(0.0998)	(0.0986)
Some college	-0.1159	-0.1260
	(0.0967)	(0.0961)
University degree or post-grad studies	-0.1742**	-0.2046**
	(0.0888)	(0.0878)
AC at home	0.2769***	0.2494***
	(0.0746)	(0.0741)
AC at work	0.0644	0.0350
	(0.0685)	(0.0677)
Spain	0.0451	0.0313
	(0.0779)	(0.0782)
"rates" version of the	-0.0458	-0.0543
questionnaire	(0.0641)	(0.0638)
Has high blood pressure		0.2099***
		(0.0793)
Bad cholesterol		0.1608**
		(0.0817)
Is diabetic		0.2438**
		(0.1169)
Has COPD		0.2816***
		(0.0769)

The omitted category is excellent health. Standard errors in parentheses; ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. [a]: Recoded to zero if the respondent did not report income.

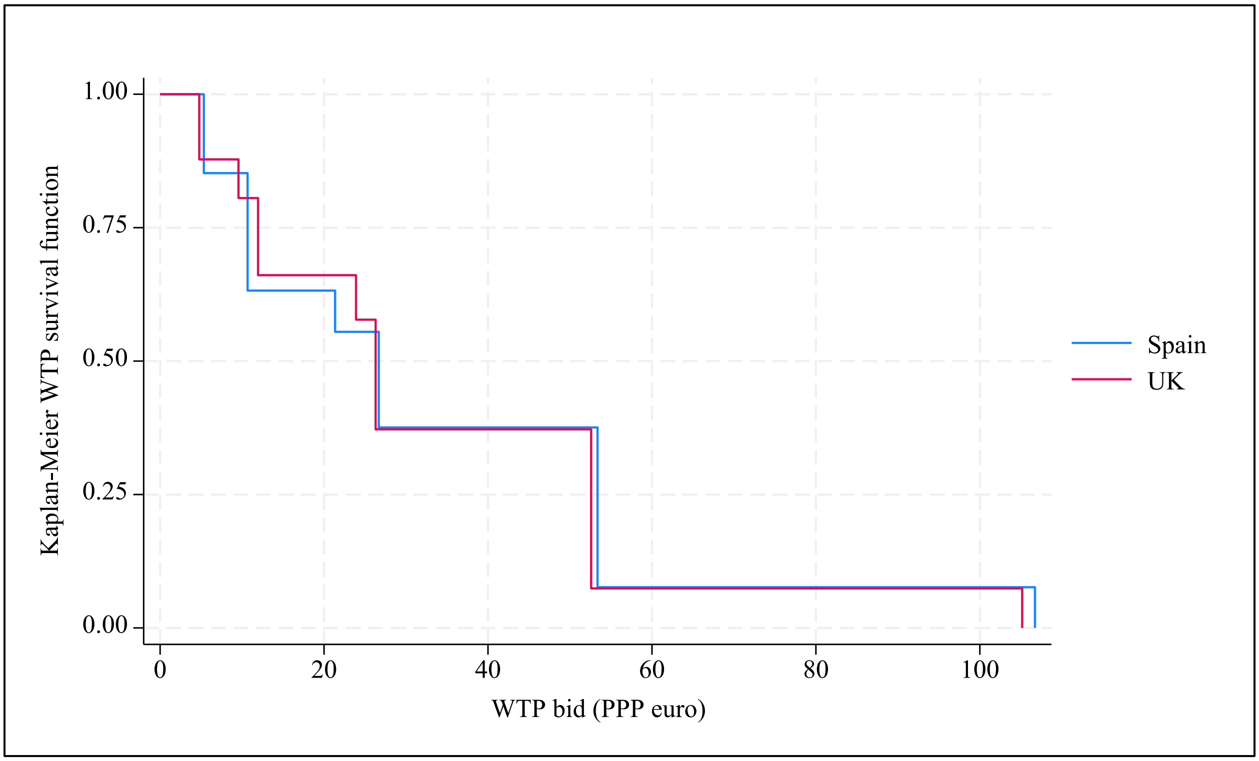
Table 6. Models with WTP (in thou. PPP euro) assumed to be proportional to the size of the mortality risk reduction delivered by the program.

	(A)	(B)	(C)
Mortality risk reduction	1623.059*** (81.021)	1713.918*** (107.226)	1740.392 (134.601)
Mortality risk reduction × Spain		-210.736 (163.319)	-211.181 (163.329)
Mortality risk reduction × "rates" version of the questionnaire			-52.597 (161.700)

Standard errors in parentheses; ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively.

Appendix.

Figure A.1. Non-parametric estimates of the survival function of WTP, namely 1-F(WTP), where F( ) denotes the cumulative distribution function of WTP. The survival function depicts a non-parametric estimates of the percentage of respondents willing to pay any given amount for the Spain and the UK samples.



The Kaplan-Meier estimator is a non-parametric estimator of the survival function of the WTP, namely 1-F(x), where F( ) is the cdf of the WTP and x is a specified value. It is an estimate of the probability that the WTP exceeds value x and is obtained as $\hat{S}(x) = \prod_{i:x_i \leq x} \left(1 - \frac{d_i}{n_i}\right)$, where d_i is the count of respondents whose WTP must be comprised between x_{i-1} and x_i, and n_i is the number of respondents whose WTP exceeds x_i.

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