URBAN ENVIRONMENTAL HEALTH AND SENSITIVE POPULATIONS: HOW MUCH ARE THE ITALIANS WILLING TO PAY TO REDUCE THEIR RISKS?*

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Last revised: 15 March 2006
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Abstract: We use contingent valuation to elicit WTP for a reduction in the risk of dying for cardiovascular and respiratory causes, the most important causes of premature mortality associated with heat wave and air pollution, among the Italian public. The purpose of this study is three-fold. First, we obtain WTP and VSL figures that can be applied when estimating the benefits of heat advisories, other policies that reduce the mortality effects of extreme heat, and environmental policies that reduce the risk of dying for cardiovascular and respiratory causes. Second, our experimental study design allows us to examine the sensitivity of WTP to the size of the risk reduction. Third, we examine whether the WTP of populations that are especially sensitive to extreme heat and air pollution—such as the elderly, those in compromised health, and those living alone and/or physically impaired—is different from that of other individuals. We find that WTP, and hence the VSL, depends on the risk reduction, respondent age and health status. WTP increases with the size of the risk reduction, but is not strictly proportional to it. All else the same, older individuals are willing to pay less for a given risk reduction than younger individuals of comparable characteristics. Poor health tends to raise WTP, all else the same. Our results support the notion that the VSL is "individuated."

JEL Classification: Q51, Q54.
Keywords: Contingent Valuation, Willingness to Pay, Mortality Risk Reductions, Value of a Statistical Life, Scope Test, Cardiovascular and Respiratory Risks, Heat Waves, Heat Advisories, Adaptation to Climate Change, Air Pollution, Premature Mortality.

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* This research was conducted within the research project "Climate Change and Adaptation Strategies for Human Health in Europe" (cCASHh) (EVK2-2000-00670), funded by the European Commission, DG Research.
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I. Introduction and Background

The 2001 Intergovernmental Panel on Climate Change (IPPC) report warns that an increase in the frequency and/or intensity of heat waves will raise heat-related premature mortality, primarily among the elderly and the urban poor, with the largest increases in thermal stresses occurring in cities in temperate regions. Urban areas in Europe could, therefore, experience increases in mortality outcomes associated with extremely hot weather. Historically, cardiovascular diseases have accounted for 13-90% of the increase in mortality during and following a heat wave, cerebrovascular disease accounted for 6-52%, and respiratory diseases for 0-14% (Kilbourne, 1997).

Air pollution is another major concern for urban areas. A raft of epidemiological studies documents both short-term spikes in mortality during high pollution episodes and long-term effects of exposures to elevated levels of fine particular matter, ozone, nitrogen oxides, and sulfur dioxide. Kunzli et al. (2000), for example, estimate that for the combined population of France, Austria and Switzerland some 40,000 deaths per year are attributable to fine particulate matter, and Samet et al. (2000) that 20 to 200 lives are lost each day in US cities because of polluted air. Because air pollution has been linked to cardiovascular and respiratory effects, susceptible populations include children and fetuses, persons with cardiovascular illnesses, asthma, emphysema and chronic obstructive pulmonary disease, and the elderly (World Health Organization, 2002).

The European Union and many European countries are currently adopting policies to reduce these mortality effects. Regarding extreme heat, after the unprecedented heat wave that affected the European region in Summer 2003 and the spike in mortality that accompanied it, several countries began to implement heat advisory programs (cCASHh Research Team, 2005). Other possible policies include the creation of green islands within urban areas, retrofitting buildings, establishing climate-controlled shelters for the population, and emergency response plans. Regarding air quality, the recent Clean Air for Europe (CAFE) initiative emphasizes reductions in emissions from stationary and mobile sources.

Economists would recommend that, when setting these policies, at least some consideration be given to their costs and benefits. Ebi et al. (2004) do a complete benefit-cost analysis of the Philadelphia heat warning system. They estimate that the system saved 117 lives over 3 years, and multiply this figure by an estimate of the Value of a Statistical Life (VSL). The resulting mortality benefits greatly exceed the cost of the system. The VSL figures prominently in the cost-benefit analysis of CAFE (Hurley et al., 2005), despite the limited evidence about the estimate of the VSL in a European context.[2]

The goal of this paper is three-fold. First, we present the results of a contingent valuation survey conducted in Italy to elicit the WTP for reductions in the risk of dying for cardiovascular and respiratory causes. Our results can be used to estimate the benefits of policies that save lives that would be lost to thermal stresses, air pollution, and other environmental toxicants (e.g., certain heavy metals, such as lead). To our knowledge, this is the first such study conducted in Italy.

Second, we examine the issue of scope in a contingent valuation survey about mortality risk reductions. We vary the risk reduction to the respondents, which allows us to test whether the WTP increases with the size of the risk reduction, and, if so, by how much. Economic theory predicts that WTP should be increasing in the size of the risk reduction. This relationship is dubbed the "scope" effect, and Carson (2000) underscores that credible WTP figures for mortality risk reductions elicited through contingent valuation surveys should satisfy the scope effect requirement. In practice many CV studies fail to detect a significant relationship between WTP and the size of the risk reduction (Hammitt and Graham, 1999), and Corso et al. (2001) explore the possibility that such failure might be due to poor risk communication.

Third, we examine whether the WTP for risk reductions is different for populations that are particularly sensitive to environmental and thermal stresses and are thus the primary beneficiaries of environmental or adaptation policies. We focus on the elderly, those with a compromised cardiovascular system or serious respiratory conditions, and those that may be unable to cope with thermal stresses because they live alone and/or are physically impaired. We also examine whether persons who take care of an elderly and physically impaired family member are willing to pay more for a reduction in their *own* risks. In other words, does this experience change their preferences for risk and income?

Our findings support the notion that the VSL is "individuated" (Smith and Evans, 2004; Sunstein, 2004): We find that it varies with the size of the risk reduction, age and health status, income, and being a caregiver. For the risk reductions considered in this survey, the VSL ranges from €0.257 million to over €5.8 million. WTP increases with the size of the risk reduction valued by respondents, but in a less than proportional fashion.

[2] Hurley et al. (2005) declined to produce VSL figures on a country-by-country basis on the grounds that original WTP data were not available and for political considerations. This suggests that it is important that

II. The Value of a Statistical Life and its Determinants

A. The Value of a Statistical Life

The VSL is the rate at which people trade off income for a risk reduction:

(1) $$VSL = \frac{\partial WTP}{\partial R} \ ,$$

where WTP signifies the willingness to pay for a change in the risk of dying, and R is the risk of dying. The VSL can equivalently be described as the total WTP by a group of N people experiencing a uniform reduction of 1/N in their risk of dying. To illustrate, consider a group of 10,000 individuals, and assume that each of them is willing to pay €30 to reduce his or her own risk of dying by 1 in 10,000. The VSL implied by this WTP is €30/0.0001, or €300,000. The concept of VSL is generally deemed as the appropriate construct for ex ante policy analyses, when the identities of the people whose lives are saved by the policy are not known yet. The mortality benefits of the policy are equal to the VSL times the number of lives saved by the policy.

B. Sensitive Populations: The Elderly

Deaths linked with environmental exposures and extreme heat occur disproportionately among the elderly. This has led to the question whether the VSL should be adjusted for age. Proponents of such an adjustment argue that the VSL should be lower for older persons because they have a shorter remaining lifetime. To see how this claim compares with economic theory, consider the life cycle model, according to which an individual at age j receives expected utility V_j over the remainder of his lifetime:

European Union-wide figures be corroborated with evidence from the individual countries.

(2) $$V_j = \sum_{t=j}^{T} q_{j,t}(1+\rho)^{j-t} U_t(C_t),$$

where V_j is the present value of expected future lifetime utility. In equation (2), $U_t(C_t)$ is the utility of consumption in each period, $q_{j,t}$ is the probability that the individual survives age j to period t, and ρ is the subjective rate of time preference. T is the maximum lifetime. The specific expression of the budget constraint of the individual depends on the assumptions about opportunities for borrowing and lending. If, for example, it is assumed that the individual can borrow and lend at the riskless rate *r*, but never be a net borrower, and that the individual's wealth constraint is binding only at T, the VSL at age j, which is defined as the WTP at age j for a marginal change in D_j, the probability of dying at age j, is equal to:

(3) $$VSL_j = (1-D_j)^{-1} \sum_{t=j+1}^{T} q_{j,t}(1+\rho)^{j-t} \frac{U_t(C_t)}{U_t^{'}(C_t)},$$

where D_j is the probability of dying at age j (see Usher, 1973; Conley, 1976; Bergstrom, 1982; Cropper and Sussman, 1990).

If the term $\frac{U_t(C_t)}{U_t^{'}(C_t)}$ is constant with respect to age, then it can be brought outside of the summation in (3), implying that WTP is proportional to the discounted remaining life years. If, in addition, the discount rate is zero, then WTP for a reduction in the risk of dying is indeed strictly proportional to remaining life years. In sum, adjusting VSL for age to make it proportional to expected remaining life years relies on two restrictive assumptions: (i) that the utility divided by marginal utility does not vary with age, and (ii) that the discount rate is zero. There is no particular reason to believe that these assumptions should be true in practice. For example, if the marginal utility of consumption increases with age, then it is no longer appropriate to assume that the WTP is proportional to remaining life years.[3]

Shepard and Zeckhauser (1984) assume that the utility function is of the form C^{β}, and consider (i) the situation where the individual is completely self-sufficient and cannot borrow or lend, and (ii) the extreme opposite—perfect markets—in which individuals can borrow against future earnings and purchase actuarially fair annuities. For plausible values of β, in the former case the WTP for a risk reduction has an inverted-U shape that peaks when the individual is in his 40s, and in the latter it declines monotonically beginning at age 20. Some empirical support has been found for both predicted relationships (e.g., Jones-Lee et al., 1985; Johannesson et al., 1997; Krupnick et al., 2002, and Alberini et al., 2004).

C. Other Sensitive Populations

Equation (3) can be used to examine the value placed on risk reductions by persons with chronic cardiovascular and respiratory illnesses. In equation (3), a person with a chronic illness has a higher probability of dying in his j-th year of age, D, and lower probabilities of surviving to future ages. However, it is not clear how the remaining terms in (3) depend on health status, implying that theory does not offer predictions about the effect of impaired health on the VSL.

Krupnick et al (2002) and Alberini et al. (2004) find that, if anything, people with chronic cardiovascular and respiratory illnesses are willing to pay slightly *more*, rather

[3] Hammitt (2000) notes that the number of future life years at risk declines with age, and so does the opportunity cost of spending on risk reduction (as savings accumulate and the investment horizon approaches). The net effect may cause VSL to fall or rise with age.

than less, to reduce their own risk of dying. It remains to be seen whether this result is borne out in other studies as well.

Many of the people that died prematurely in the Chicago 1995 heat wave were persons with mobility impairments, and elderly persons living alone. Lacking air conditioning in their homes, and unable to get out and reach climate-controlled environments (Klinenberg, 2002), these individuals had been in some cases dead for days before worried neighbors called the police.[4] During the heat wave in Europe in Summer 2003, the highest increase in the mortality rates was observed in nursing homes (cCASHH Research Team, 2005).

III. Estimating the VSL: Revealed v. Stated Preference Approaches

The VSL has been estimated through a variety of methods. One method is to infer it from the additional compensation that workers must be offered for them to accept riskier jobs. In compensating wage studies, hourly or annual wages are regressed on individual characteristics thought to affect wage rates (e.g., education, experience, etc.), job and industry characteristics, plus workplace fatal and non-fatal injury risks (Viscusi, 1993). Viscusi and Aldy (2003) provide a comprehensive survey of compensating wage studies in the US and other countries. For the US they recommend VSL figures in the range from $4 to $9 million, for the UK in the range of $4 to $11 million (2000 dollars).

[4] For the week between July 14 and 20, 1995, epidemiologists attributed a total of 739 “excess” deaths to the heat wave. The City of Chicago reported 521 heat-related deaths, based on autopsies and police reports. Over 70% of the heat related casualties were persons older than 65 (Klinenberg, 2002, p. 18-19). Klinenberg does not report exactly how many of these elderly victims lived alone, but his examination of social worker and police reports suggests that this happened quite frequently and that this may become a serious concern in the future, due to the projected increase in the number of elderly people living alone (Klinenberg, 2002, chapter 1).

The VSL figures resulting from compensating wage studies are frequently transferred to the environmental policy context (US EPA, 2000).

The estimates of the VSL based on compensating wage studies are affected by serious limitations. For starters, the approach assumes, without testing, that workers are perfectly aware of their workplace risks. In addition, workers are typically assigned the workplace fatality rate within their occupation or industry. This introduces a measurement error in the risk variable.[5] In practice, there is likely to be a considerable degree of heterogeneity in risk among workers within an industry and occupation group, and individual risks are likely to be correlated with observable worker characteristics. This would be the case, for example, if adult males in the fast food industry are assigned to early or late night shift, when robberies are more likely to occur, and younger and female workers are assigned to daytime shifts. The correlation between the measurement error and other worker characteristics entering in the wage equation results in biased OLS estimates of the coefficient on risk. The direction and magnitude of the bias is unknown (Black and Kniesner, 2003).

Self-selection bias (resulting in endogeneity of risks and wages) is another problem in compensating wage studies. Arabsheibani and Marin (2000) propose a two-stage estimation approach to deal with self-selection and heterogeneity of preferences for risk and income among workers, but later warn about the difficulty of identifying good instruments for one's choice of job and workplace risks (Arabsheibani and Marin, 2001).

Measurement errors and self-selection are likely reasons why an earlier effort to estimate a compensating wage model for Italian workers (Barone and Nese, 2002) failed

[5] If industry-specific risk rates are used, for example, a secretary working for a mining firm and a miner would be ascribed the same workplace risks.

to detect a significant relationship between wage rates and objectively measured job risks. Moreover, compensating wage studies are not suitable for studying the preference of the elderly and of sensitive groups, such as those with mobility impairments, because these groups are typically no longer in the labor force.

The value that people place on risk reductions can be also be inferred from purchases of safety devices (e.g., smoke detectors), from the extra price people pay for products that are safer than others (e.g., automobiles with side airbags), or from the time spent on risk-reducing behaviors (such as fastening seat belts when driving, etc.). Again, such studies assume that people know exactly the risk reductions afforded by these purchases and behaviors (Blomquist, 2004).[6]

In principle, it is possible to estimate the VSL using hedonic regressions that relate housing prices and wages to climate (Moore, 1998) or air quality (Portney, 1981), but doing so relies on rather restrictive assumptions, namely that, after controlling for all else, any observed differences in home prices are solely due to differences in perceived health risks (thus ruling out amenity effects). In addition, in hedonic pricing studies it is often difficult to disentangle the effect of environmental externalities from that of other neighborhood characteristics.

We use contingent valuation, a survey-based approach that asks individuals to report directly their willingness to pay (WTP) for a specified—and hypothetical—reduction in their own risk of dying. The VSL is then approximated as WTP/ΔR, where ΔR is the risk reduction. One advantage of using the contingent valuation (CV) method is that respondents can be informed about their mortality risks and be told exactly the

[6] Greenstone and Ashenfelter (2004) use speed limits in the US and the associated increase in driving times to peg the VSL implicit in the States' adoption of such speed limits.

extent of the risk reduction they are to value. In addition, a CV study can be tailored to the specific type of risk being considered, a feature that is especially attractive to us, given the dearth of VSL figures specific for the cardiovascular and respiratory risks typical of thermal stresses and air pollution, and to the population of interest, including sensitive subpopulations.

Contingent valuation is not exempt from limitations. The approach is sometimes criticized because it *is* hypothetical. Researchers have explored various techniques for increasing the credibility of the responses to the payment questions, including reminders of one's budget constraint (a technique adopted here). When valuing health, it is also possible to supplement the valuation questions with questions eliciting actual expenses incurred by the respondent to reduce risks or improve health (see Alberini and Krupnick, 2000, and more recently Chestnut et al., 2005, for a comparison of cost-of-illness and WTP estimates).

Since people often struggle with the concept of (small) probabilities, a CV survey about risk reduction must devise intuitive and clear ways—such as visual aids (see Corso et al., 2001)—of communicating quantitative information about risks to the respondents. It is also important for the researcher to test the validity of the WTP responses by checking—through regression analysis—that they are correlated in predictable ways with variables suggested by economic theory, such as income, the size of the risk reduction, and other individual characteristics of the respondents. In our survey, we implement all of these techniques and approaches to make sure that the WTP responses—and hence the VSL estimates—are credible.

IV. The Survey

A. Cardiovascular and Respiratory Mortality Risk Questionnaire

As mentioned, many environmental and thermal stresses are linked with excess deaths for cardiovascular and respiratory causes. Our questionnaire elicits WTP for reductions in the risk of dying for these causes from a sample of Italian citizens. The risk reduction we ask people to value is of a private nature. Our questionnaire is self-administered by the respondent using the computer at centralized facilities. This allows us to tailor risks and scenarios to the respondent's individual circumstances (e.g., age, gender, and health status) and avoids interviewer bias.[7]

Our respondents were recruited by CIRM, a professional survey firm, among the residents aged 30-75 of five cities (Venice, Milan, Genoa, Rome and Bari). This firm maintains a database of potential respondents that is reasonably representative of the population of the major Italian cities for income, gender, age and education. Potential survey respondents were contacted by telephone and offered a gasoline coupon worth €20 for their participation in the survey. To avoid self-selection into the sample, prospective participants were not told what the exact topic of the survey would be.

Our goal was to have N=200 for each city; each city subsample was to be stratified by age and gender, with respondents equally divided among three broad age groups (30-44, 45-59, and 60-75) and a roughly equal number of men and women. Within these age groups, the sample was to be as representative as possible of the population of those cities in terms of income and education. The final survey took place on 31 May-9 June 2004, resulting in 801 completed questionnaires. After excluding one

[7] The questionnaire development work relied on focus groups and one-on-one testing, and the final questionnaire was tested in a small pilot study with 20 respondents.

ineligible respondent who was 77 years old, we are left with a sample of 800 completed questionnaires.

B. What Type of Risk Reduction?

We wish to emphasize that climate change or pollution was never mentioned to the respondent in this survey: People were to value reductions in their own risk of dying for cardiorespiratory causes, the risks arising from genetic factors, lifestyle, or simply mirroring population rates. We chose to do so for three reasons. First, an earlier study by Johannesson et al. (1991) suggests that people are capable of grasping such risks and willing to pay to reduce them.[8] Second, we wished to keep the risk reduction a private good, because it is difficult to identify the altruistic components of WTP, and to account for them appropriately to avoid double-counting.[9] Third, linking risk changes to emissions reductions or adaptation to climate change would require that we educate respondents about them, quantify effects, and address the uncertainty associated with them. In our opinion, doing so would have resulted in an excessively heavy cognitive burden, which prompted us to choose a context-free risk reduction.

Clearly, one limitation of our approach is that we miss altruistic components of benefits, and that we do not know if, and by how much, how our estimates of WTP

[8] In Johannesson et al.'s 1991 study, patients with high blood pressure were recruited at a clinic in Sweden. The survey questionnaire asked these persons to report their subjective baseline risk of dying from heart diseases and other complications associated with hypertension, and to estimate the risk reduction afforded by the medication they took on a regular basis. These persons were subsequently asked to report their WTP to continue taking the medication.

[9] Economic theory concludes that if altruism is non-paternalistic, then altruistic benefits should not be counted in a benefit-cost analysis. Altruistic benefits may be counted when altruism is paternalistic (i.e., one cares for the benefits of risk reductions experienced by others, but not about the costs that the policy will impose on others) (Johannson, 1993).

should be adjusted to account for characteristics of the risks that would be addressed by a proposed policy (e.g., uncontrollability v. voluntarity, dread, etc.).[10]

Although our survey does not explicitly mention heat waves and the reasons why old people living alone and persons with mobility impairments might be at higher risk during heat waves, we still wish to find out how these people value reducing their risk of dying for cardiovascular and respiratory causes. In addition, we wish to see whether *familiarity* with and being responsible for people that due to age or mobility impairments need assistance on a day-to-day basis influence our respondents' WTP to reduce their own risks.

C. Structure of the Questionnaire

The questionnaire is divided into seven sections. In section 1, after querying the respondent about gender and age, we ask the respondent if he or she has ever been diagnosed to have certain cardiovascular and respiratory conditions (including heart disease, chronic obstructive pulmonary disease, asthma, and emphysema), or their precursors (high blood pressure, elevated LDL cholesterol,[11] diabetes). In section 2, we ask questions assessing the respondent's health over the last four weeks, as well as any physical mobility limitations and psychological well-being. Our questions are adapted

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[10] Some studies suggest that altruistic components of WTP may be significant (see, for example, Jones-Lee et al., 1985). Johannesson et al. (1996) compared the WTP for a private and a public risk reduction within the same context (auto safety), and found that the latter was actually less than the former. There is limited evidence about how different attributes of a risk will result in different valuation. Magat et al. (1996), for example, find individuals indifferent between mortality risks from road traffic accidents and from fatal lymph cancer. Chilton et al. (2002) conclude that "the impact of these perceptions is a great deal less pronounced than has been by the value differentials that are currently implicit—and in some cases, explicit—in public policy making." Tsuge et al. (2005) have recently deployed conjoint choice questions (of which dichotomous-choice contingent valuation is a special case) to study how WTP depends on the attributes of the risk reduction to be valued.

[11] This type of cholesterol is commonly dubbed "bad" cholesterol because it can clog arteries, causing a heart attack or a stroke.

from the Short Form 36 (SF36) questionnaire, which is widely used in medical research to assess physical and emotional health.

Section 3 provides a simple probability tutorial, leading to the explanation of one's chance of dying, which is expressed as X in 1000 over 10 years, and is graphically depicted using a grid of 1000 squares.[12] White squares represent survival, while blue squares represent death. Respondents were tested for probability comprehension. Specifically, we asked people which person had the higher risk of dying (the one whose risk is 5 in 1000, or the one whose risk is 10 in 1000?) and which of these two persons they would prefer to be.

In section 4, we acquaint respondents with the concept that it *is* possible to reduce one's risk of dying, and that many people do so on a routine basis. For example, we tell respondents that a pap smear can reduce the risk of dying of cervical cancer (in women) and that blood pressure medication reduces the risk of dying of a heart attack. We then introduce cardiovascular and respiratory illnesses. We list examples of cardiovascular and chronic respiratory ailments, along with the symptoms, causes and treatments, and then ask the respondents if they are currently taking any actions to prevent (or any treatment to cure) cardiovascular and respiratory illnesses.

In section 5, the respondent's risk of dying for *cardiovascular and respiratory illnesses* is shown by orange squares in the grid of 1000 squares, and the chance of dying *for all other causes* is shown by blue squares. By placing both types of risks on the same grid, we hope to give the respondent a sense of cardiovascular risks' share of total

[12] Assuming that the risk reduction is spread evenly over the 10 years, this is equivalent to X in 10,000 a year. As in Alberini et al. (2004), our initial focus groups revealed that people find the risk reductions more credible when they are presented using a 10-year frame. In addition, the visual aids based on the X in 1000 risk reduction are much clearer than those depicting an X in 10,000 risk.

mortality risks. The questionnaire emphasizes that cardiovascular and respiratory risks increase—both in absolute magnitude and as a share of total risks—as one gets older.

We computed the baseline risks (both all-cause baseline risks and cardiovascular/respiratory baseline risks) using population life tables (ISTAT, 2001), and so the baseline risks are the population mortality rates by age and gender. However, we told respondents that the risks depicted on the screen applied to a person of their same age and gender, similar health status and similar risk-reducing behavior. We did so—as in Viscusi et al. (1991)— because we wanted to avoid situations where people reject baseline risks, which would create problems of errors-in-variables in our econometric model (Greene, 2003).

Section 6 presents the hypothetical risk reduction scenario. People were offered a reduction of X in their cardiovascular and respiratory risks over the next 10 years, where X ranges from 1 to 22, depending on the respondent's age and gender. The extent of the risk reduction was shown visually by green squares on the grid. An example of a screen presenting the risk reduction to the respondent is shown in Figure 1.[13] Baseline risks and risk reductions are displayed in table 1.

Table 1 shows clearly that there are a total of nine different risk reductions, which should allow us to identify the relationship between WTP and risk change. This table also shows that all-cause and cardiorespiratory baseline risks increase with age, and so do the

[13] Respondents were randomly assigned to one of two versions of the questionnaire. In Version 1, they were asked to imagine that a new medical test is available that is safe and without side effects, and delivers the stated risk reduction, but must be done and paid for every year to be effective. The payment mechanism is a co-pay much like the fee for medical tests charged by the Italian national health care system. Version 2 the questionnaire is similar in all respects, except that people are simply asked to imagine that it is possible to reduce their risk by a certain amount, without mentioning any other specifics. Our focus groups indicated that people accepted such an abstract risk reduction, and that with this approach they tended to focus more sharply on the size of the risk reduction, without being distracted by other details. We compare the groups of respondents that received these two "treatments" elsewhere (Alberini and Chiabai, 2006).

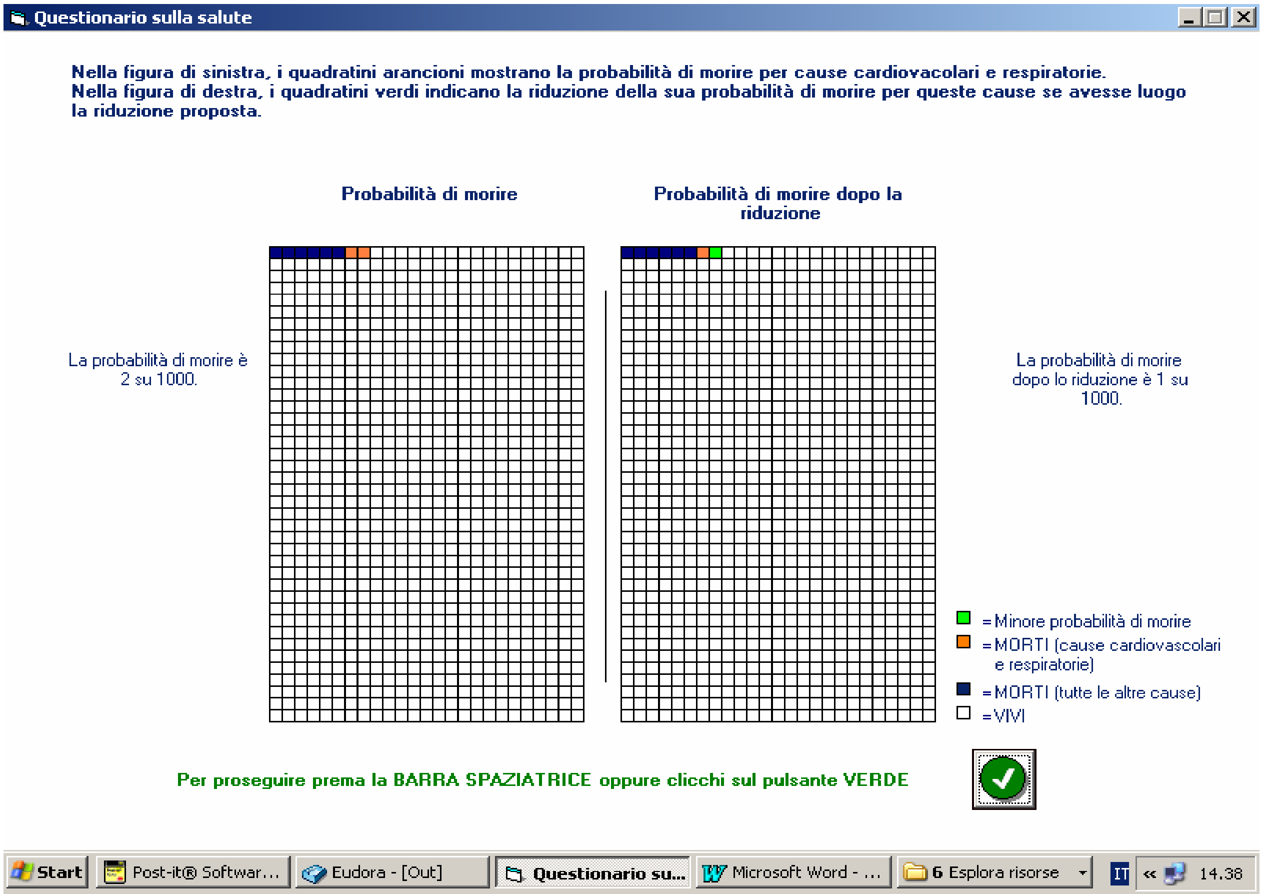
cardiorespiratory risk reductions. The initial focus groups suggested that it was necessary to offer greater risk reductions to older respondents to prevent them from dismissing the scenario off-hand. One disadvantage of this experimental design is that, since the risk reductions tend to be correlated with baseline risks, which in turn increase with age, it does not allow us to identify the separate effects of age and baseline risks on the WTP for a given risk reduction.

The payment question is in a dichotomous choice format with one or two follow-ups.[14] The bid amounts (representing annual payments) are shown in table 2. Respondents were randomly assigned to one of these four bid sets.

Sections 7 and 8 of the questionnaire deal with future risk reductions (Alberini and Chiabai, 2006), and section 9 concludes the survey with the usual socio-demographic questions and debriefing questions.

[14] Respondents who answered “yes” to the first payment question were queried about a higher amount, while respondents who answered “no” to the first payment question were asked whether or not they would purchase the proposed risk reduction for a lower price. When a respondent answered “no” to both the initial payment question and the follow-up question, he or she was asked whether he would pay anything at all to obtain the risk reduction, and, if so, exactly how much.

Figure 1. Presentation of risk reduction in the questionnaire.



(Translation)

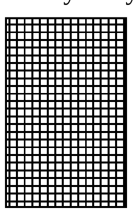
Health Questionnaire.

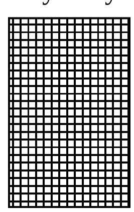
In the grid on the left, the orange squares show your probability of dying for cardiovascular and respiratory causes. In the grid on the right, the green squares show the reduction in your probability of dying for these causes.

Probability of dying

Probability of dying after the risk reduction

The probability of dying (for cardiovascular and respiratory causes) is 2 in 1000





After the risk reduction, the probability of dying (for cardiovascular and respiratory causes) is 1 in 1000

□ = reduction in the probability of dying
□ = dead (for cardiovascular and respiratory causes)
□ = dead (for all other causes)
□ = alive

To continue, press the space bar or click on the green button.

Table 1. Baseline risks and risk reductions assigned to respondents in the survey.

Males				Females			
Age	Baseline risk (all causes of death)	Baseline risk (cardiovasc and respiratory)	Risk reduction (cardiovasc and respiratory)	Age	Baseline risk (all causes of death)	Baseline risk (cardiovasc and respiratory)	Risk reduction (cardiovasc and respiratory)
30-34	12	2	1	30-34	5	2	1
35-39	15	4	2	35-39	8	2	1
40-44	23	6	3	40-44	13	4	2
45-49	37	11	5	45-49	20	5	2
50-54	62	18	3 or 6	50-54	38	7	3
55-59	105	34	5 or 8	55-59	49	13	4
60-64	177	64	5 or 10	60-64	80	25	4 or 5
65-69	297	122	5 or 12	65-69	138	54	5 or 8
70-74	478	225	12 or 22	70-74	247	118	8 or 12

Table 2. Bid amounts.

initial bid (euro per year)	if yes	if no
110	250	70
250	500	110
500	950	250
950	1200	500

V. Econometric Models

A. Models of Willingness to Pay

In this paper, attention is restricted to the willingness to pay for the risk reduction that begins immediately. Let $V(y,R)$ denote the individual's indirect utility, which depends on income and the risk of dying R. Willingness to pay, $WTP*$, is defined as the maximum amount of money that can be taken away from an individual at lower level of risk to keep his utility unchanged. Formally (and conditionally on individual characteristics),

(4) $$V(y-WTP^{*},R_1)=V(y,R_0),$$

where y is income, R_0 is the baseline risk and R_1 is residual risk after the reduction (R_0 > R_1, where $R_1 = R_0 - \Delta R$, and ΔR is the risk reduction). Willingness to pay should, therefore, depend on the baseline and final risk, income, and individual characteristics. We assume that for respondent i:

(5) $$WTP_i^* = \exp(\mathbf{x}_i \beta_1) \cdot (\Delta R_i)^{\beta_2} \cdot (R_{0i})^{\gamma} \cdot \exp(\varepsilon_i)$$

where **x** is a 1×k vector of individual characteristics thought to influence WTP (including income) and ε is an error term. On taking logs, we obtain:

(6) $$\log WTP_i^* = \mathbf{x}_i \boldsymbol{\beta}_1 + \beta_2 \log \Delta R_i + \gamma \log R_{0i} + \varepsilon_i \,.$$

In our broadest model, therefore, log WTP depends on log baseline risk, log risk change, and other individual characteristics. In practice, in our study baseline risk is highly correlated with variables included in **x,** such as age and gender. To investigate the effect of the latter on WTP^*, we are therefore forced to suppress baseline risk from the regression, which means that the coefficient on age captures the effect of both different baseline risk *and* different valuation of a given risk reduction:[15]

(7) $$\log WTP_i^* = \mathbf{x}_i \boldsymbol{\beta}_1 + \beta_2 \log \Delta R_i + \varepsilon_i$$

We expect β_2 to be positive. The magnitude of this coefficient determines the sensitivity of willingness to pay to scope, i.e., to the size of the risk reduction. If $\beta_2 = 1$, willingness to pay is strictly proportional to the size of the risk reduction (Hammitt and Graham, 1999).

[15] In other words, our survey design does not allow us to separately identify the effect of baseline risk, risk reduction and age on WTP. In addition, since cardiovascular and respiratory risks increase with baseline risks, it cannot provide a clean test of the effect of competing risk, as discussed in Eeckhoudt and Hammitt (2001). These author examine how the willingness to pay to reduce a specific cause of death changes as the risk of dying for a competing cause changes. They describe the "why bother" effect, whereby an old and

B. Estimation Strategy

To estimate equation (7), where WTP^* is the respondent's unobserved willingness to pay, we begin by recognizing that our sample is a mix of continuous and interval-data observations on WTP. Observations on a continuous scale are contributed by those respondents who answered "no" to the initial and follow-up payment questions, and finally reported an exact WTP amount. All others contribute interval-data observations.[16]

We assume that WTP^* follows the Weibull distribution with shape parameter θ and scale σ_i, where $\sigma_i = \exp(\mathbf{x}_i \boldsymbol{\beta}_1 + \beta_2 \log \Delta R_i)$, which means that ε_i is type I extreme value with scale θ, and that equation (7) is an accelerated-life model. The log likelihood function is thus:

$$(8) \qquad \sum_{i=1}^{n} I_i \cdot \log f(WTP_i^*; \lambda) + (1 - I_i) \cdot \log\left[F(WTP_{Hi}; \lambda) - F(WTP_{Li}; \lambda)\right]$$

where I_i is a dummy indicator that takes on a value of one if the respondent reported his WTP amount on a continuous scale, and zero otherwise; WTP_L and WTP_H are the lower and upper bound of the interval around the respondent's (unobserved) WTP amount; *F*(WTP;λ) and *f*(WTP;λ) are the cdf and pdf of a Weibull variate, and λ is comprised of $\boldsymbol{\beta}_1$, β_2 and θ (to be estimated by the method of maximum likelihood).

C. The Choice of the Independent Variables

Our WTP regression controls for the age of the respondent. To test whether health status influences willingness to pay, we include in the model a dummy (ATRISK)

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chronically ill individual with a large risk of dying for, say, cardiovascular causes would be willing to pay very little, or nothing at all, to reduce his or her risk of dying associated with, say, air pollution exposure.

equal to one if the respondent suffers from chronic cardiovascular and respiratory illnesses, is diabetic, has high blood pressure, or has high cholesterol.

Willingness to pay should, all else the same, increase with the respondent's income. We divide household income by the number of family members (PCAPPINC), and enter this variable in the model along with a companion missing income dummy (MISSINC).[17] Other individual characteristics thought to influence WTP are whether the respondent is married (MARRIED), a dummy denoting whether the respondent has dependent children of ages 12 and younger (CHILDREN12), and a college education dummy (COLLEGE).

Finally, we examine the effect on WTP of physical mobility limitations by using the dummy IMPEDITO and that of being elderly and living alone using the dummy (OLDALONE). The questionnaire asks people whether they take care of a family member or other person who, due to age or physical limitations, needs day-to-day assistance, whether in the respondent's home or elsewhere. For those who do, the dummy HELP takes on a value of one. We include this dummy to check the effect of familiarity with old age, physical limitations and experience as a caregiver. City dummies are included to account for possible differences in the cost of living.

VI. The Data

A. Individual Characteristics of the Respondents

[16] For example, suppose that an individual was offered an initial "price" of €250 for a specified risk reduction, which he declined to pay. He was then queried about €110, which he was willing to pay. We interpret this to mean that his true willingness to pay lies between €110 and €250.

[17] Our results are virtually unchanged if we replace income per household member with household income. The only coefficient that changes is that on income itself, which is roughly 40% of the coefficient on income per household member.

Descriptive statistics of our survey respondents are displayed in table 3. As shown in table 3, the sample is relatively well-balanced in terms of gender, with only a slight prevalence of women. The average respondent is 50 years old. Persons aged 65 and older account for 18% of the sample.

Seventy percent of the respondents are married, and 17% have children younger than 12 years of age. Eleven percent of the respondent has a college degree, although only 3.44% of our respondents of ages 65 and older do. Regarding household income, 85% of the respondents answered the income question, reporting an average income of €21,386 a year, which corresponds to an average per household member of €8,513 a year.

Table 3. Descriptive statistics of the respondents.

Variable	**Valid obs.**	**Mean**	**Stand. Devn.**	**Minimum**	**Maximum**
Male (dummy)	800.00	0.48	0.50	0	1
Age (years)	800.00	50.47	13.50	30	75
OLDER65 (dummy)	800.00	0.18	0.38	0	1
Married (dummy)	800.00	0.70	0.46	0	1
CHILDREN12 (dummy)	800.00	0.17	0.37	0	1
College degree (dummy)	800.00	0.11	0.32	0	1
Household size	800.00	2.89	1.22	1	7
Household income (euro/yr)	684.00	21,386	9,707	6,000	60,000

Table 4 reports descriptive statistics about the health status of the sample. About a quarter of the respondents has high blood pressure, 16% has high low-density cholesterol, and serious cardiovascular illnesses are reported by 3-6% of the sample. Emphysema, chronic bronchitis and asthma affect 1 to 9 percent of the sample.

This means that 49% of the sample has been diagnosed to have at least one chronic cardiovascular or respiratory illness, or high blood pressure or high cholesterol, or diabetes (“at risk”). These chronic illnesses or pre-conditions are reported more frequently by the elderly: 71% of those aged 65 or older have at least one such condition.

Table 4. Health status of the respondents.

Illness or activity	Percent of the sample
high blood pressure	25.63
high "bad" cholesterol	16.13
Angina	3.13
heart attack	4.75
Diabetes	7.50
other cardiovascular illness	6.25
Stroke	1.50
Emphysema	1.38
Chronic bronchitis	6.75
Asthma	8.75
At risk for cardiovascular and respiratory causes	48.9
Cancer	2.63

The sample is comparable to the Italian population at large in terms of composition by gender (males account for 47% of the Italian population) and educational attainment (10.2% of the Italians have a college degree). In terms of health status, this sample reports rates of illness that are very similar to those observed in an earlier study in almost all of the same cities (Alberini et al., 2006).

Finally, our sample respondents' income is somewhat lower than that of the Italian population: In 2002, the average household income among the latter was €27,868, and the average income per household member was roughly €10,000 (Banca d'Italia, 2002). (This is to be expected, since respondents were asked to take the questionnaire at a centralized facility. Presumably, the likelihood of participating is higher for persons with lower incomes, more free time, and lower opportunity cost of time.)

The difference with respect to the income population statistics is particularly stark among our respondents of ages 65 and older. For these persons, the average household income in our sample is €14,385, and the income per household member is €7,443, whereas the corresponding statistics for the population in the same age group in 2002 were €20,000 and €12,000, respectively. These findings imply that it is important to control for sociodemographics in our WTP regressions and to use population values for the covariates when making predictions for the population's WTP.

B. Risk Comprehension and Acceptance of Risk

Our questionnaire included two quizzes intended to check whether the respondents had grasped the concept of probability explained in the probability tutorial. The first quiz asks people to indicate which of two people has the higher risk of dying—the person with a 5 in 1000 risk of dying, or the person with the 10 in 1000 risk of dying. About a quarter of the respondents failed this quiz, but almost eighty percent of those who did promptly corrected their answer when offered the opportunity to do so.

The second quiz asks people which of those two persons they would rather be. About two-thirds of the sample selected the person with the lower risk, 16% chose the person with the higher risk, and the remainder said that they were indifferent. When queried again, less than 5% of the sample (38 people) confirmed that they wished to be the person with the higher risk of dying.

The responses to a debriefing question at the end of the questionnaire indicate that 27.84% of our respondents felt that the baseline risks stated to them were roughly what they expected, 15.23% thought that they were higher than expected, 11.36% judged them to be lower than expected, and the remainder (45.57%) had no idea what to expect.

C. Responses to the Payment Questions

Our first order of business is to check that the percentage of "yes" responses to the initial payment question declines with the bid amount. As shown in table 5, this is indeed the case, implying that the responses to the payment questions are reasonable and consistent with economic theory. The percentage of “yes” responses is about 65% at the lowest bid amount included in the study, and 41.3% at the highest. The follow-up questions provide additional information about the distribution of WTP: WTP is less than €70 a year for about 27% of the sample and greater than €1200 for about 23%.

Table 5. Percentage “yes” responses to the initial payment question.

Initial bid	% yes
110	65.19
250	51.95
500	42.76
950	41.30

Next, we consider the sequences of responses to the initial and follow-up payment questions. As is often the case in contingent valuation surveys, the most frequently observed pair of responses is “no”-“no” (NN) (40.13%), followed by “yes”-“yes” (28.63%). YN and NY combinations account for 20% and 11.25% of the sample, respectively.

VII. Model Results

We begin with reporting the estimation results for equation (7) in table 6. For good measure, our regressions are based on a “clean” sample that excludes those respondents who failed both probability quizzes on the first attempt (26 respondents). In addition, we exclude from the sample those respondents who were assigned a risk reduction greater than 12 in 1000. This decision is motivated by two reasons. First, we wish to be consistent with a companion survey in the Czech Republic, where ΔR ranged from 1 to 12 in 1000 over 10 years. Second, ΔR greater than 12 in 1000 over 10 years is outside of the range appropriate for the policy applications of this paper.[18]

Model (A) in table 6 shows that the coefficient β_2 on the log risk change is positive, as expected, and significant at the 5% level, indicating that WTP does increase with the size of the risk reduction. However, this coefficient is significantly less than 1, implying that WTP is less than proportional to the size of the risk reduction, and is equal to about 0.34, which is consistent with earlier studies (e.g., Alberini et al., 2004; Alberini, 2005).

WTP is significantly lower among the elderly. All else the same, persons aged 60-69 and persons aged 70 and older have WTP amounts that are 58% and 41% of those for persons aged 30-59.[19] Persons with cardiovascular problems are willing to pay, all else the same, about 45% more than persons in better health. This effect goes against the conventional wisdom implicit, for example, in the use of quality-adjusted life years (QALY) measures, which discount programs or interventions that save the lives (or extend the lifetimes) of persons in poor health (see Hammitt, 2002).

Finally, WTP increases with income, an effect that is significant at the 10% level. Males have a lower WTP and married people have WTP values that are about 24% larger than the other individuals, but these effects are not statistically significant. Likewise,

[18] Including observations with larger risk changes does not change the results appreciably. The coefficient on log risk change is slightly smaller and significant at the 10% level, but not at the 5% level. Income exhibits a somewhat stronger association with WTP, approaching significance at the 5% level. All other coefficients are virtually the same as those of table 6. We initially included in the regressions city dummies to control for differences in the cost of living and other locale-specific factors that could influence WTP, but since the coefficients on these dummies were jointly insignificant, we omit them from the specifications in table 6.

[19] These results are confirmed when we run a regression where we enter a continuous age variable, rather than age group dummies. The coefficient on age is negative, and significant at the 10%. Most other coefficients are similar to, but less strongly statistically significant than, their counterparts in model (A) of table 6. A quadratic relationship between age and WTP was attempted, but rejected in favor of linear form.

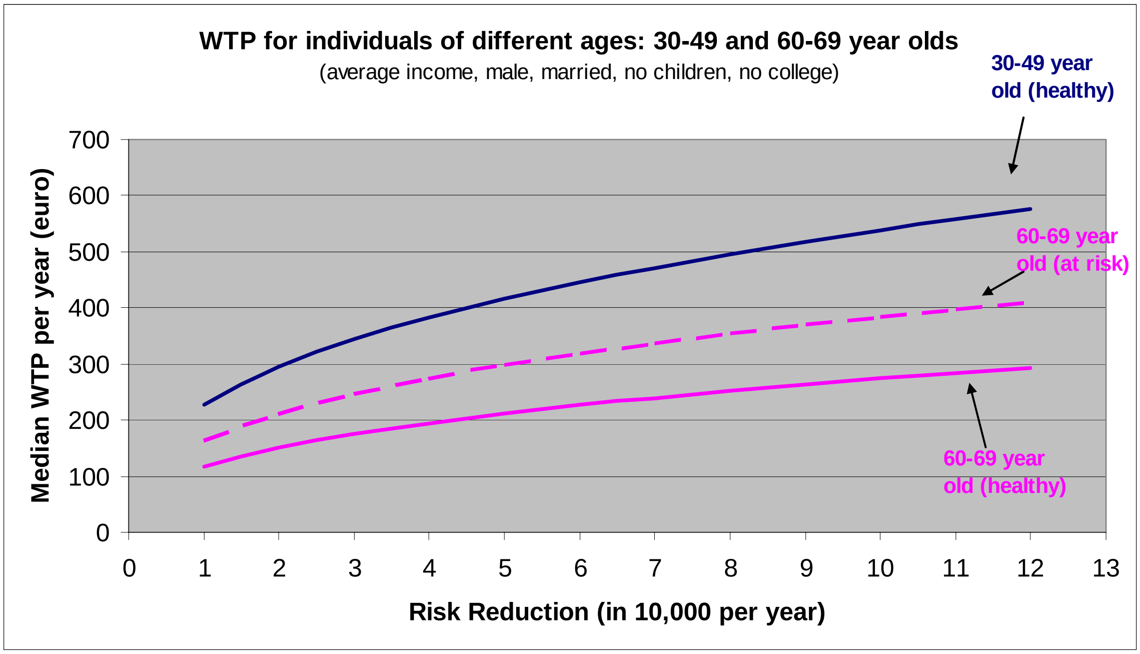
having young children or a college degree does not have a statistically discernible effect on WTP.

Table 6. WTP for risk reduction, equation (7). Weibull WTP, continuous/interval-data model. Cleaned sample (deleted FLAG1=1).

	(A) Base sample (N=756)		**(B) Respondents with income <€9000 and WTP at least €950/yr excluded (N=696)**	
Variable	**Coeff.**	**t stat.**	**Coeff.**	**t stat.**
Intercept	8.8724	6.334	9.1013	6.278
Log risk reduction (β_2)	0.3388	2.217	0.3725	2.359
Age 50-59 dummy	-0.2225	-0.945	-0.2318	-0.964
Age 60-69 dummy	-0.5407	-2.210		
Age 70 and older dummy	-0.8869	-2.281		
Age 60 and older dummy			-0.6759	-2.682
ATRISK dummy	0.3687	2.715	0.3365	2.361
Income per household member (000 euro)	0.0247	1.715	0.0308	2.000
Missing income dummy	0.0545	0.252	0.2198	0.936
Male dummy	-0.2139	-1.560	-0.2557	-1.761
Married dummy	0.2134	1.421	0.2303	1.423
Children of ages 12 and younger dummy	0.0197	0.103	0.0299	0.154
College degree dummy	0.1278	0.599	0.1754	0.792
Weibull shape parameter	0.7098	21.000	0.7011	19.974

Model (B) of table 6 is similar, except that we further excluded from the sample those respondents whose WTP is at least 10% of household income, just in case these persons may have failed to take their budget constraint into account when answering the WTP questions.[20] Doing so leaves us with a sample where the very elderly (those aged 70 and older) account for only 1% of the total. Their WTP cannot be reliably contrasted with that of persons in the other age groups, and we are forced to collapse the elderly and the very elderly into one “over 60” dummy. All coefficients are very similar to their counterparts in model (A); WTP becomes slightly more responsive to the size of the risk reduction, and the coefficient on income is significant at the 5% level.

Figure 2.



The main findings of model (A) are summarized in figure 2, where we plot the median WTP for a male aged 30-49 and one aged 60-69. Both of these individuals are assumed to be married and without young children, and to have income per household member equal to the Italian average (€10,000). Figure 2 confirms that WTP grows with the size of the risk reduction, but at a decreasing rate. It is also clear that—if both individuals are assumed healthy—the older individual's WTP is lower than that of the younger individual for all risk reductions. The 30-49-year-old's median WTP ranges from €182 a year (for the risk reduction of 1 in 10,000 a year) to €559 (for the risk

[20] Virtually all of the respondents that were excluded using this criterion were people who were willing to pay at least €950 a year for the risk reduction, but whose household income was €9000 or less.

reduction of 12 in 10,000 a year). By contrast, the 60-69-year-old's annual median WTP ranges from €101 to €309 a year. If the latter is assumed to be in compromised health, however, his WTP is higher than before for all risk reductions, and is considerably closer to that of the younger individual.

We added regressors—one at the time—to model (A) and model (B) in table 6 to test whether WTP is different for other sensitive subpopulations. In these runs, we found that people with mobility impairments (who account for 13.2% of the sample) were willing to pay slightly more for the risk reduction, but this effect is not significant at the conventional levels. Those respondents who are 65 or older and live alone are prepared to pay less for the risk reduction, but the coefficient on this variable is small and insignificant at the conventional levels.[21] This result, however, should be interpreted with caution, because these individuals make up a tiny share of the sample (3.37%). Finally, caregivers (16.85% of the sample) are willing to pay 59% more for any given risk reduction. This effect is statistically significant at the 1% level. Perhaps taking care of people with limitations due to age and impaired mobility raises the salience of the risk reduction valued in this questionnaire to the respondents, and this in turn increases willingness to pay.

As shown in table 7, the VSL of 30-49 year-old is €2.282 million or €4.865 million (based on median and mean WTP, respectively) when referred to a 1 in 1000 risk reduction over 10 years, and €0.831 million or €1.772 million when referred to a 5 in 1000 risk reduction. For the healthy 60-69 year-old, the VSL is €1.160 million or €2.475 (1 in 1000 risk reduction, median and mean WTP, respectively) and €0.422 million or

[21] For example, when OLDALONE is added to specification (B) of table 6, its coefficient is estimated to be -0.1941 (t statistic 0.75).

€0.901 million (5 in 1000 risk reduction, median and mean WTP). When this older person is assumed to be in compromised health, however, the VSL is considerably higher, ranging from half-million euro to €3.465 million, depending on the size of the risk reduction and the welfare statistic used.

Our estimates provide independent support for the EU-wide figures recommended in the cost-benefit analysis of the Clean Air for Europe program, which are €0.980 million and €2.0 million, respectively (2000 euro). Our VSL figures bracket those used by the European Commission, whose baseline central VSL is €1.4 million, but are below that used by the US Environmental Protection Agency ($6.1 million, 1999 dollars), which is dominated by labor-market VSL values (US EPA, 2000).

Table 7. VSL in million Euro. VSL is median/mean WTP, divided by the risk reduction.

Size of the risk reduction	**30-49 year-old (healthy)**		**60-69 year-old (healthy)**		**60-69 year-old (at risk)**	
	Based on median WTP	based on mean WTP	Based on median WTP	Based on mean WTP	Based on median WTP	Based on mean WTP
1 in 10,000 a year	2.282	4.865	1.160	2.475	1.625	3.465
5 in 10,000 a year	0.831	1.772	0.422	0.901	0.592	1.262

Calculations assume average income per household member in Italy, male, married, no children, no college degree.

VIII. Discussion and Conclusions.

The responses to the WTP questions in our survey are broadly consistent with the economic paradigm and suggest that people understood the commodity being valued. We find that WTP does increase with the size of the risk reduction, but in a less than proportional fashion (see Alberini et al. (2004), Alberini (2005), and Hammitt and Graham (1999). Consequently, the VSL is *not* a fixed constant for all risk reductions. For the risk reductions studied in this paper (1 to 12 in 10,000 a year, or 1 to 12 in 1,000 over 10 years), the VSL ranges from €0.244 million to €4.865 million.

We paid special attention to (sub-) populations that are regarded as especially sensitive to the environmental health risks in urban areas. We found that indeed the WTP for a given risk reduction, and hence the VSL, is lower among the elderly and higher among subjects at elevated risk because of existing cardiovascular and respiratory conditions or pre-conditions. Respondents were willing to pay more when they are caregivers for impaired or elderly family members. Perhaps familiarity with physical impairments and old age increases the salience to the respondents of the risk reductions valued in this questionnaire. Taken together, our regression analyses support the claim that the VSL is "individuated" (i.e., individual-specific).[22]

How do these figures compare with estimates of the VSL from other studies? In Maddison and Bigano (2003) the amenity effects of climate are captured in the housing and the labor markets. They find that, absent any changes in the precipitation patterns, the Italians would be prepared to pay about €325-370 per household per year to *avoid* a one-degree increase in July temperatures. Combining these results with the excess deaths recorded in Rome in Summer 2003, and assuming that the value of the disamenity reflects entirely the excess deaths due to the heat wave, we obtain a VSL of €3.345 million,[23] a figure that falls within the range of VSL estimated directly in our study.

The VSL figures elicited from this study can be used for estimating the mortality benefits of adaptation policies that save lives during heat waves and of other environmental policies that limit exposure to pollutants that cause or worsen

[22] Whether or not government agencies should account for individuated VSLs is, of course, another matter. Sunstein (2004) acknowledges the informational burden required of agencies, should they pursue full individuation, but also points out that in some cases, as in the case of clean air, individuation is not desirable, because people cannot be excluded from clean air.

[23] See Alberini et al. (2006) for details on these calculations. They should be regarded as an upper bound, because they assume that housing price and wage differentials reflect solely differences in mortality risks across locales with different climate, and that amenity effects and aesthetics do not matter.

cardiovascular and respiratory illnesses. For example, for thermal stresses, based on Kovats (2003), we estimate that (holding the population constant) in 2020 in Rome an additional 46 lives would be lost to cardiovascular and respiratory deaths because of hot weather among people younger than 65 and 121 among the 65 year-olds and older.

We use estimates of the VSL based on median WTP for individuals at risk and for the corresponding risk reductions (about 1 in 10,000 a year, and 2.5 in 10,000 a year, respectively, for people up to age 65 and for 65-year-olds and older). These two VSL figures are equal to €1.798 million and €0.914 million. Assuming no discounting for the sake of simplicity, the monetized mortality damages in the absence of adaptation programs are thus €193 million for the year 2020 (2004 euro) for the city of Rome alone.

To illustrate how our VSL figures could be used in the air pollution context, WHO (2002) estimates that 3473 deaths would be avoided among the population of age 30 and older if it were possible to reduce particulate matter of diameter less than 10 micron (PM10) from the current average (52.6 $\mu g/m^3$) in the eight largest Italian cities to 30 $\mu g/m^3$. These figures do not distinguish for the ages and susceptibility of the persons exposed to outdoor air pollution and assume only long-term mortality effects, so we use the VSL of a person of average age (40.6 years) and income for a risk reduction of about 6 in 10,000 annually. The relevant VSL figures are €0.741 million (based on median WTP) or €1.580 million (based on mean WTP). This target level of particulate matter would, therefore, bring reductions in mortality worth €2,574 million to €5,489 million per year.

References

Alberini, Anna and Aline Chiabai (2006), "Discount Rates in Risk v. Money and Money v. Money Tradeoffs," FEEM working paper 8.2006, Milan, Italy, January.

Alberini, Anna (2005), "What is a Life Worth? Robustness of VSL Values from Contingent Valuation Surveys," *Risk Analysis*, 25(4).

Alberini, Anna, Aline Chiabai and Giuseppe Nocella (2006), "Valuing the Mortality Effects of Heat Waves," in Bettina Menne and Kris Ebi (eds.), *Climate Change Adaptation Strategies for Europe*, Darmstadt: Springer.

Alberini, Anna, Maureen Cropper, Alan Krupnick and Nathalie Simon (2004), "Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the U.S. and Canada," *Journal of Environmental Economics and Management*, 48(1), 769-792.

Alberini, Anna, Alistair Hunt and Anil Markandya (2006), "Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-country Contingent Valuation Study," *Environmental and Resource Economics,* 33(2), 251-264.

Alberini, Anna and Alan Krupnick (2000), "Cost-of-Illness and WTP Estimates of the Benefits of Improved Air Quality: Evidence from Taiwan," *Land Economics,* 76(1), February.

Arabsheibani, G.R. and A. Marin (2000), "Stability of Estimates of the Compensation for Danger," *Journal of Risk and Uncertainty*, 20(3), 247-269.

Arabsheibani, G.R. and A. Marin (2001), "Self-selectivity Bias with a Continuous Variable: Potential Pitfall in a Common Procedure," *Applied Economics*, 33, 1903-1910.

Banca d'Italia (2002), *I bilanci delle famiglie italiane nell'anno 2000*, Supplementi al Bollettino statistico anno XII n. 6.

Barone, Adriana and Nese, Annamaria (2002), "Rischio sul Lavoro e Premio Salariale in Italia," *Lavoro e relazioni industriali*.

Bergstrom, Theodore C. (1982), "When is a Man's Life Worth More than His Human Capital?" in Michael W. Jones-Lee (ed.), *The Value of Life and Safety*, Amsterdam: North-Holland.

Black, Dan A. and Thomas S. Kniesner (2003), "On the Measurement of Job Risk in Hedonic Wage Models," *Journal of Risk and Uncertainty*, 27(3), 205-220.

Blomquist, Glenn C. (2004), "Self-protection and Averting Behavior, Values of Statistical Life, and Benefit Cost Analysis of Environmental Policy," *Review of Economics of the Household*, 2(1), 89-110.

Carson, Richard T. (2000), "Contingent Valuation: A User's Guide," *Environmental Science Technology*, 34, 1413-1418.

cCASHh Research Team (2005), "Climate Change and Adaptation Strategies for Human Health in Europe," Research Report to the European Commission, EVK2-CT-2000-00070, Rome, January.

Chestnut, Lauraine G., Mark A. Thayer, Jeffrey K. Lazo, and Stephen K. Van Den Eeden (2006), "The Economic Value of Preventing Respiratory and Cardiovascular Hospitalizations," *Contemporary Economic Policy*, 24(1), 127-143.

Chilton, Susan, Judith Covey, Lorraine Hopkins, Michael Jones-Lee, Graham Loomes, Nick Pidgeon, and Anne Spencer (2002), "Public Perceptions of Risk and Preference-based Values of Safety," *Journal of Risk and Uncertainty*, 25(3), 211-232.

Conley, B.C. (1976), "The Value of Human Life in the Demand for Safety," *American Economic Review*, 66(1), 45-55.

Corso, Phaedra S., James K. Hammitt, and John D. Graham (2001), "Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation," *Journal of Risk and Uncertainty*, 23(2), 165-184.

Cropper, Maureen L. and Frances G. Sussman (1990), "Valuing Future Risks to Life," *Journal of Environmental Economics and Management*, 19(2), 160-174.

Ebi, Kristie L., Thomas J. Teisberg, Laurence S. Kalkstein, Lawrence Robinson, and Rodney F. Weiher (2004), "Heat Watch/Warning Systems Save Lives: Estimated Cost and Benefits for Philadelphia 1995-98," *Bulletin of the American Meteorological Society*, August, 1-7.

Eeckhoudt, Louis R. and James K. Hammitt (2001), "Background Risks and the Value of a Statistical Life," *Journal of Risk and Uncertainty*, 23, 261-279.

Greene, William H. (2003), *Econometric Analysis*, 5th edition, Upper Saddle River, NJ: Prentice Hall.

Greenstone, Michael and Orley Ashenfelter (2004), "Using Mandated Speed Limits to Measure the Value of a Statistical Life," *Journal of Political Economy*, 1(2), 112.

Hammitt, James K. (2000), "Valuing Mortality Risk: Theory and Practice," *Environmental Science and Technology*, 34, 1396-1400.

Hammitt, James K. (2002), "QALYs Versus WTP," *Risk Analysis*, 22(5), 985-1001.

Hammitt, James K. and John D. Graham (1999). "Willingness to Pay for Health Protection: Inadequate Sensitivity to Probability?" *Journal of Risk and Uncertainty*, 8, 33-62.

Hurley, Fintan, Alistair Hunt, Hilary Cowie, Mike Holland, Brian Miller, Stephen Pye, and Paul Watkiss (2005), *Methodology for the Cost-benefit Analysis for CAFE. Volume 2: Health Impact Assessment*, Report to the European Commission, DG Environment, AEAT/ED51014, Oxon, UK, February.

Intergovernmental Panel on Climate Change (IPCC) (2001), *IPCC, 2000. Impacts, Adaptation and Vulnerability. The Contribution of Working Group II to the Third*

Scientific Assessment of the Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

Johannesson, Magnus, Per-Olov Johansson and Karl-Gustav Lofgren (1997), "On the Value of Changes in Life Expectancy: Blips Versus Parametric Changes," *Journal of Risk and Uncertainty*, 15(3), 221-239.

Johannesson, Magnus, Bengt Jonsson, and Lars Borquist (1991), "Willingness to Pay for Antihypertensive Therapy—Results for a Swedish Pilot Study," *Journal of Health Economics*, 10, 461-474.

Johannesson, Magnus, Per-Olov Johansson and Richard M. O'Conor (1996), "The Value of Private Safety Versus the Value of Public Safety," *Journal of Risk and Uncertainty*, 13, 263-275.

Johansson, Per-Olov (1993), *Cost-Benefit Analysis of Environmental Change*, Cambridge, UK: Cambridge University Press.

Jones-Lee, Michael W. et al. (1985), "The Value of Safety: Results of a National Sample Survey," *Economic Journal*, 95, 49-72.

Kilbourne, E.M. (1997), "Heat Waves and Hot Environments," in E. K. Noji (ed.), *The Public Health Consequences of Disasters*, Oxford, UK: Oxford University Press.

Klinenberg, Eric (2002), *Heat Wave*, Chicago: University of Chicago Press.

Kovats, Sari (2003), "cCASHh: Estimates of temperature-related mortality in Italy," report prepared for cCASHh workpackage 8, London School of Hygiene and Tropical Medicine.

Krupnick, Alan, Anna Alberini, Maureen Cropper, Nathalie Simon, Bernie O'Brien, Ron Goeree, and Martin Heintzelman (2002), "Age, Health and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Study of Ontario Residents," *Journal of Risk Uncertainty*, 24, 161-186.

Künzli, N. et al. (2000), "Public-health impact of outdoor and traffic-related air pollution: a European assessment," *The Lancet*, 356, 795-801.

Magat, Wesley A., W. Kip Viscusi and Joel Huber (1996), "A Reference Lottery Metric for Valuing Health," *Management Science*, 42(8), 1118-1130.

Maddison, David and Andrea Bigano (2003), "The Amenity Value of the Italian Climate", *Journal of Environmental Economics and Management*, 45: 319-332.

Moore, Thomas Gale (1998), "Health and Amenity Effects of Global Warming", *Economic Inquiry*, 471-488.

Portney, Paul R. (1981), "Housing Prices, Health Effects, and Valuing Reductions in Risk. of Death," *Journal of Environmental Economics and Management*, 8, 72-78.

Samet, Jonathan M., Francesca Dominici, Frank C. Curriero, Ivan Coursac, and Scott L. Zeger (2000), "Fine Particulate Air Pollution and Mortality in 20 US Cities, 1987-1994, *New England Journal of Medicine*, 343(24), 1742-1749.

Shepard, D.S., and R.J. Zeckhauser (1984), "Survival Versus Consumption," *Management Science*, 30(4), 423-439.

Smith, V. Kerry and Mary Evans (2004), "Individuated VSLs and the Dead Anyway Hypothesis," unpublished paper, North Carolina State University, available at http://www2.ncsu.edu/unity/lockers/users/v/vksmith/research/CEnREP_PUB_PAPERS.htm

Sunstein, Cass R. (2004), "Are Poor People Worth Less than Rich People? Disaggregating the Value of a Statistical Life," AEI-Brookings Joint Center for Regulatory Studies Working paper 04-05, Washington, DC, January.

Tsuge, Takahiro, Atsuo Kishimoto and Kenji Takeuchi (2005), "A Choice Experiment Approach to the Valuation of Mortality," *Journal of Risk and Uncertainty*, 31(1), 73-95.

US Environmental Protection Agency (2000), Guidelines for Preparing Economic Analyses, EPA-R-00-003, Washington, DC, September.

Usher, Dan (1973), "An Imputation to the Measure of Economic Growth for Changes in Life Expectancy," in Milton Moss (ed.), *The Measurement of Social and Economic Performance*, Studies in Income and Wealth, vol. 38, New York: National Bureau of Economic Research.

Viscusi, W. Kip (1993), "The Value of Risks to Life and Health," *Journal of Economic Literature*, 31(4), 1912-1946.

Viscusi, W. Kip and Joseph E. Aldy (2003), "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World," *Journal of Risk and Uncertainty*, 27(1), 5-76.

Viscusi, W. Kip, Wesley A. Magat, and Joel Huber (1991), "Pricing Environmental Health Risks: Survey Assessments of Risk-risk and Risk-dollar Tradeoffs for Chronic Bronchitis," *Journal of Environmental Economics and Management*, 21, 32-51.

World Health Organization (2002), Health Aspects of Air Pollution. Results from the WHO Project 'Systematic Review of Health Aspects of Air Pollution in Europe.' WHO Report E83080, Rome, June.