Fondazione Eni Enrico Mattei

NOTA DI LAVORO

03.2009

Rates of Time Preferences for Saving Lives in the Hazardous Waste Site Context

By **Anna Alberini**, University of Maryland, and Fondazione Eni Enrico Mattei

Stefania Tonin and **Margherita Turvani**, University IUAV of Venice

SUSTAINABLE DEVELOPMENT Series
Editor: Carlo Carraro

Rates of Time Preferences for Saving Lives in the Hazardous Waste Site Context

By Anna Alberini, University of Maryland, and Fondazione Eni Enrico Mattei
Stefania Tonin and Margherita Turvani, University IUAV of Venice

Summary

What is the rate at which people discount future lives saved? The answer to this question has important implications when comparing policies on the grounds of cost per life saved, especially in the context of hazardous waste site remediation, where risk reductions may occur at different times, depending on the permanence of the remedy. We estimate this rate by asking a sample of Italian residents to choose between saving 100 lives now and X lives in T years, where both X and T are varied to the respondents. Assuming constant exponential discounting, the responses to these questions imply a rate of time preference for saving lives of 12%. There is little evidence that this rate is systematically associated with observable individual characteristics of the respondent. There is, however, strong evidence that it declines with the time horizon when the lives would be saved, ranging from 16% for T=10 to less than 4% for $T^{3}40$. We fit a hyperbolic discount model, finding that it yields a similar value of the discount function for T=10 (the shortest horizon we used in the survey), and that it discounts the future less heavily than the regular exponential discounting model for longer time horizon. We apply our estimated discount functions to two alternate remedial plans for a heavily contaminated area in Italy, and find that—due to the high estimated discount rates—the less permanent solution is found to be more cost-effective.

Keywords: Value of a Statistical Life, Latent Risk Reductions, Individual Discount Rates, Rate of Time Preference for Saving Lives, Contaminated Sites, Remediation

JEL Classification: J17, I18, K32, Q51, Q53

Address for correspondence:

Anna Alberini
AREC, 2200 Symons Hall
University of Maryland
College Park MD 20742
USA
Phone: +1 301 405 1267
Fax: +1 301 314 9091
E-mail: aalberini@arec.umd.edu

Rates of Time Preferences for Saving Lives in the Hazardous Waste Site Context

by

Anna Alberini, Stefania Tonin, and Margherita Turvani

1. Introduction and Motivation

Many environmental policies reduce human health risks and thus save lives. To compute the (monetized) benefits of these policies, it is necessary to know at what rate the beneficiaries of these policies are willing to trade off income for risk reductions. This can be done by observing risk-wage compensating differentials in the labor market (Viscusi, 1993; Viscusi and Aldy, 2003), purchases of safety equipment (Jenkins et al., 2001), time spent in risk-reducing activities (Blomquist et al., 1988), or by directly asking people to report their Willingness to Pay for a hypothetical risk reduction (Johannesson et al., 1997, Krupnick et al., 2002). Economic theory suggests that people should discount such risk reductions if they occur in the future but are paid for now (Cropper and Sussman, 1990), and several studies have documented the existence and degree of such discounting (Horowitz and Carson, 1990; Johannesson and Johansson, 1996; Alberini et al., 2004, Tsuge et al., 2005, Hammitt and Liu, 2004, Alberini and Chiabai, 2007, Alberini et al., 2006).

In other cases, agencies are interested in comparing programs or regulations solely on the grounds of cost per life saved. If the alternative programs or regulations save lives at different times, this raises the question whether lives should be discounted for cost-effectiveness calculation purposes, and, if so, at what rate. The rate at which lives saved are discounted also matters in environmental and public health policy situations where policymakers must trade off immediate with future health risk reductions. Hazardous waste policies and regulations are prominent examples of such situations.

To illustrate, waste disposal and treatment methods pose health risks to people at different times (Dijkgraaf and Vollebergh, 2004): landfills can contaminate groundwater used for drinking purposes with pathogens and chemical pollutants, while incineration of municipal waste (an option frequently used in many European countries) may create dioxins and ash emissions that increase the risk of cancer and cardiovascular and respiratory damage in the long term.

In the US, sites where hazardous wastes have contaminated soil and groundwater, potentially threatening human health, are covered by a major federal program (the Superfund program), and a host of State and local enforcement-based and voluntary cleanup programs.[1] By statute, remedial activities under the Superfund program are expected to incorporate a preference for permanent remediation (see Hamilton and Viscusi, 1995), but protection of human health at contaminated sites addressed by other programs is often attained by means of less permanent engineering solutions (e.g., caps, other barriers, natural attenuation, etc.) and/or institutional controls (e.g., by fencing the site and prohibiting access, restricting the use of the property, disallowing the use of the

[1] First passed in 1980 as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and subsequently re-authored and extensively amended in 1986, the Superfund program provides for both emergency, short-term "removals" and longer-term remedial actions, which imply more or less permanent measures to reduce contamination and thus the risks it poses to human health and ecological systems. The statute and subsequent EPA guidelines spell out cleanup criteria to be adopted at the most egregious contaminated sites in the nation, which are placed on the so-called National Priorities List and may qualify for publicly financed cleanup. Specifically, EPA managers are directed to select target risk reductions to protect human health and meet any "legally applicable" or "relevant and appropriate" standards (e.g., maximum contaminant limits in groundwater), regardless of cost (Revesz and Stewart, 1995). When selecting among alternative remedies that attain the selected target risk reduction, consideration must be given to cost-effectiveness, practicable technologies *and* permanent remediation—as opposed to simple containment to prevent migration of pollutant and to limit exposure.

groundwater on the premises, etc.) (US General Accounting Office, 1997). Since less permanent remediation methods are typically less expensive in the short term but imply higher risks in the future, when the remedy fails, the true cost-effectiveness of a remedial method depends on the rate of time preference for saving lives.

Local government and municipalities implicitly trade off human health risks incurred at different times when they allow the construction of aboveground v. underground storage tanks for petroleum products and other regulated substances at a specific locale. With the former, the risks to human health are the immediate risks associated with catastrophic failure, fires and explosions, while underground tanks tend to contaminate soil and groundwater, creating cancer risks in the long term in the population exposed.

As a final example of a situation with short- and long-term health risk tradeoffs, consider chlorination in drinking water systems. Chlorination removes biological contaminants from drinking water, which implies an immediate reduction in the risk of dying for the population served by that water supply system, but the chlorination process creates trihalomethanes (THM), which are carcinogenic. The latency period associated with these carcinogens is thought to be in the 20-30-year range (Carson and Mitchell, 2006), and every year in the US between 2 to 100 deaths have been attributed to THM from public water supply systems. The set of regulatory options (e.g., keeping the current chlorination standards and accepting the present THM levels and associated future health risks, or imposing removal of excess THM) should depend, among other things, on how heavily the future deaths are discounted relative to immediate deaths.[2]

---

[2] Carson and Mitchell (2006) use contingent valuation methods to find out whether the benefits of THM removal after water chlorination—measured by people's Willingness to Pay for the corresponding

There has been considerable debate in policy circles whether future lives should be discounted and government agencies have traditionally used discount rates in the 4-10% range (see Sunstein and Rowell, 2007, for a nice summary of arguments in favor or against discounting, and of agency practices). In this paper, we ask three research questions: First, what is the public's rate of time preference for saving lives? Second, is there evidence of heterogeneity in such a rate, and, if so, does the heterogeneity depend systematically on observable individual characteristics? Third, are people's responses consistent with the constant exponential discounting rate, or is there evidence of hyperbolic discounting, whereby the discount rate is higher for shorter time horizons and lower for the more distant future (Shane et al., 2002, Viscusi and Huber, 2006)?

Two possible approaches are possible when estimating the public's the rate of time preference for saving lives. The first is to ask people to engage in person tradeoffs, which elicit the number of lives saved in the future that makes an individual indifferent with saving a specified number of lives now (see Polinder et al., 2005). The second is to ask people to choose between saving a given number of lives now and X lives saved in Y years (Cropper et al., 1991, 1992). While the former approach produces a respondent-specific marginal rate of substitution for lives saved at different times, which can then be averaged over the sample, the latter requires formal statistical analysis to produce the mean or median marginal rate of substitution. In both cases, the individual is asked to think as if he were the social decision maker.

We adopt the choice approach, which we specialize to public programs for the remediation of hazardous waste sites. Our choice questions are thus in contrast with those

reduction in the risk of dying of cancer—are worth the extra costs of this additional process, which may be financially burdensome for smaller water treatment plants.

in Cropper et al., 1991, 1992, who kept their life saving programs abstract and generic. We administer such choice questions to a sample of residents of four Italian cities.

Briefly, we find that—if we assume constant exponential discounting—the discount rate is 12.36%. This rate is considerably higher than that traditionally used by government agencies (4-10% in the US and 4% in the European Union). There is evidence of considerable heterogeneity in personal discount rates, but little evidence that they depend on observable individual characteristics of the respondents. Even more important, the discount rate tends to be lower for longer time horizons, i.e., when lives would be saved in a more distant future. We fit a hyperbolic discounting model to our survey responses, which predicts less heavy discounting than the constant exponential discounting model for the longest time horizons in our sample.

The remainder of the paper is organized as follows. In section 2, we describe the relevant discounting literature. Section 3 describes the survey questionnaire and the administration of the survey. Section 4 presents the model, section 5 the data and section 6 the estimation results. Section 7 provides concluding remarks.

2. Previous Literature

It is generally accepted among economists that people discount future payoffs or losses. This is explained by impatience, desire for immediate gratification, and the perceived possibility that the future payoff or cost may not materialize, among other reasons (Frederick et al., 2002). Frederick (2006) distinguishes between discounting the utility of a future payoff, and the possibility that the utility of a given payoff is lower in the future. In any case, the rates at which people (i) discount money in the present versus a sum in the future, (ii) give up money now to obtain future health or increases in the chance of surviving, or (iii) prefer to save lives now instead of saving them in the future is an important determinant of private investment decisions and public environmental health and safety policies.

Personal discount rates—namely, item (i)—can be estimated by observing tradeoffs between immediate and future costs and payoffs. The discount rate for money has been studied, for example, by observing people's decisions to purchase electrical appliances or their acceptance of early retirement offers. Eletrical appliance that are more energy efficient and have lower running costs are generally more expensive to buy, and consumers have exhibited discount rates of 17-20% for air conditioners (Hausman, 1979), 102% for gas heaters, 138% for freezers and 243% for electrical water heaters (Ruderman et al., 1987). The large difference with respect to market interest rates may have been due to lack of awareness of the true costs of running appliances or limited access to credit, which may have prevented arbitrage (Frederick et al., 2002).

Warner and Pleeter (2001) observe the decision to turn down or accept early retirement separation packages by members of the Armed Forces, concluding that the discount rates are 10-21% among officers, and 35%-57% among enlisted personnel. In field experiments, Harrison et al. (2002) estimate the average discount rate of a sample of Danes to be about 28%, with individual discount rates depending on individual characteristics of the study participant. Earlier studies (e.g., Benzion et al., 1989) obtained even higher estimates. Personal discount rates have tended to be especially high when small sums are involved (Frederick et al., 2002).

In many environmental and safety contexts, it is important to find out how much the beneficiaries of a policy that save lives are willing to pay *now* to secure a reduction in the risk of dying that occurs *in the future*, i.e., item (ii) above. With many carcinogens and pollutants, for example, it may take exposure over a long period of time before the onset of symptoms or diseases, and, conversely, several years before a reduction in exposure translates into a reduction in risk. Future risk reductions are also an important consideration when the policy (e.g., an air quality program) improves environmental quality permanently.

Assuming that an individual is the beneficiary of the risk reduction, we would expect him to be willing to pay less for a risk reduction in the future than for a comparable risk reduction that takes place immediately. This is for two reasons. First, the individual may not be alive at the time in the future when the risk reduction takes place. Second, the life-cycle model implies that future risk reductions should be discounted to the present at the consumption rate of interest. With perfect capital markets, this consumption rate of interest should be equal to the market interest rate. If individuals face borrowing constraints, the consumption rate of interest may be higher than the market interest rate (Cropper and Sussman, 1990; Cropper and Portney, 1990). In earlier research, the rates at which individuals discounted future risks for current money usually fall in the range between 0.3 and 14% (Moore and Viscusi, 1990; Johannesson and Johansson, 1996; Horowitz and Carson, 1990; Alberini et al., 2006; Alberini and Chiabai, 2007; Alberini et al., 2007).[3]

[3] Using the responses to conjoint choice questions from the same survey of Italians as in this paper, Alberini et al. (2007) estimate that individuals discounted future reductions in the risk of dying associated with contaminated site exposure at a rate of 7%. One implication of this discount rate was that individuals were willing to pay for remediation, which reduces the risk of dying of cancer and other illnesses caused by

This paper, however, is primarily concerned with (iii)—the rate(s) at which people discount lives saved in the future. There is considerable disagreement in policy and academic circles about the appropriateness of discounting lives saved in the future (see Sunstein and Rowell, 2007). Revesz (1999) notes that it is generally accepted that money should be discounted because it can be invested in alternative and more profitable projects today, whereas a similar argument cannot be made with lives. There is, therefore, no reason to think in the abstract that the time preference for health risks should be the same as that for money. He further distinguishes between latent environmentally-induced harm for persons who are alive today, and risks for future generations, and argues that in the former setting it makes sense to apply discounting, since an environmentally-induced illness today is worse than an environmentally-induced risk in twenty years. The standard notion of discounting cannot apply, his argument continues, with future generations.

Hahn (2005) notes that unless lives saved are discounted, it would be optimal for governments to put off safety or environmental policies indefinitely.[4] Failure to discount future risk reductions and the choice of the discount rate when discounting is done at all have resulted in confusion and conflicting claims about the cost-effectiveness of government regulatory programs (Morrall, 2003).

Another important question is whether the discount rates used by government agencies incorporate the rate of time preference of the individuals they are attempting to

---

exposure to pollutants from contaminated sites, but they would be prepared to accept smaller risk reductions (which we interpret to mean less aggressive remedial action) if such risk reductions could be delivered sooner. They would also be prepared to accept a less permanent remedial action if the risk reduction could be initiated earlier.

[4] Lives saved, life-years or other health outcomes saved are by no means the only (physical) benefit of a policy that is discounted in government practices and analyses. For example, natural resource damage assessment and compensation posits that to make up the present loss of services of a natural resource due to an oil or chemical spill it is necessary to provide a "larger" flow of services in the future (see http://www.csc.noaa.gov/coastal/economics/habitatequ.htm, accessed 9 July 2008).

protect. Cropper et al. (1991, 1992) estimate the public's discount rate in a telephone survey of Maryland residents and a national sample. Their hypothetical questions keep the life-saving policies abstract and generic. Polinder et al. (2005) frame their question in terms of life-years saved, instead of lives saved, and challenge the notion that personal discount rates for saving lives or life-years is smaller than personal discount rates for money.

The above discussion assumes constant exponential discounting. But if people behave differently in short-run and long-run tradeoffs, and if they are more impatient in the short-run decisions than in the long-run decisions, discounting may be better captured by hyperbolic discount functions (Lowenstein and Prelec, 1992; Harvey, 1994; Laibson, 1997). There is plentiful evidence of individual behaviors consistent with hyperbolic discounting (e.g., procrastinating a chore, overeating, using mind-altering substances, etc.), and much discussion about a social planner's use of hyperbolic discounting to justify climate change mitigation decisions (Dasgupta and Maskin, 2005; Cropper and Laibson, 1999; Karp, 2005). Different reasons are mentioned in economic literature to explain why people might rationally choose hyperbolic discounting. They may prefer sure results, their preferences could change, or they may have an urgent need such as hunger or paying rent (Redden, 2007).

3. Background, Structure of the Questionnaire and Survey Administration

Our interest in the rates at which individuals discount lives is motivated by the changes in cleanup standards for contaminated sites that have recently taken place in Italy, and by the debate that surrounds them (Cerruto, 2007; Dell'Anno, 2006). Briefly, legislation addressing hazardous waste sites was first passed in Italy in 1997. The original law required remediation if the concentration of specified contaminants in soil, groundwater or surface water exceeded certain limits. In April 2006, the law was amended to require that cleanup be conducted to bring the concentrations of pollutants back to the limits spelled out in the law (or below them), but only if an initial risk assessment determines that there is sufficient exposure to these pollutants.

The new law contains an explicit preference for permanent remediation and for on-site treatment of contaminated media, but recent analyses conducted by the Italian Environmental Protection Agency and environmental organizations (APAT, 2004; Legambiente, 2005) point out that thus far the majority of remedial actions at sites on the National Priorities List have been short-term and impermanent. For this reason, we felt it was important to study people's preferences for more or less permanent remediation, and for saving lives now or in the future.

Our survey questionnaire was designed to explore these issues using a variety of techniques. In the first section of the questionnaire, we wished to investigate people's knowledge of contaminated sites, the importance they place on the adverse health consequences of exposure to pollutants and on remediation, and their opinions on a number of possible policy tools that can be used to address the problem of contaminated sites (e.g., government intervention at orphan sites, fencing off hazardous waste site to reduce exposure, stepping up monitoring and enforcement, etc.).[5]

---

[5] Since a respondent's notion of contaminated site may be different from our own, the questionnaire begins by providing a definition of contaminated site: "A contaminated site is a parcel or an area with hazardous substances that pose risks to human health or the environment, now or in the future. These hazardous substances are the result of human activities. Electromagnetic fields/pollution and air pollution are not considered contaminated sites in this questionnaire."

The second major section of the questionnaire educates people about the severity of the contaminated site problem in Italy, introduces the concept of remediation and provides examples of possible remediation technologies, pointing out that they vary in terms of cost and completion time, and that different sites and pollutants require different remedies.[6]

Once respondents had been provided information about the health effects of exposure and possible remedies and their costs, they were asked to engage in tradeoffs between the size of possible risk reductions afforded by remediation, their timing and permanence, and their cost. The analysis of the responses to these questions (section 3 of the questionnaire) is reported elsewhere (Alberini et al., 2007).

The question at the heart of this paper was placed in the fourth major section of the questionnaire. This question inquired about the respondents' rate of time preferences for saving lives. Specifically, we asked respondents which option they would prefer, a program that saves 100 lives now, or one that saves X in Y years, assuming that the cost of the two programs is the same. Both X and Y were varied to the respondents.

We use the responses to these questions to estimate the rate at which people discount lives. Unlike Cropper et al. (1991, 1992), who did not specify the exact context for the life-saving programs in the questionnaire, we told respondents clearly that these were public hazardous waste site cleanup programs.[7] By the time respondents got to the

[6] For example, pump-and-treat options are appropriate for contaminated groundwater, while bioremediation may be used at petroleum sites.

[7] For comparison, Cropper et al. (1991, 1992) ask a sample of Maryland residents, a sample of residents of the Washington, DC, area, and a national sample the following question: "Without new programs, 100 people will die this year from pollution and 200 people will die 50 years from now. The government has to choose between two programs that cost the same, but there is only enough money for one. Program A will save 100 lives now. Program B will save 100 lives 50 years from now. Which program would you choose?" The number of lives saved by program B and the number of years from now when lives are saved were varied to the respondents.

choice questions about lives saved now and lives saved in the future, they had been educated about contaminated sites, cleanup, risk reductions and other features of remediation, and had expressed their views about various aspects of possible cleanup programs. They were, therefore, well warmed up for the questions we examine in this paper.

Finally, in section 5 of the questionnaire we also asked people to express their agreement or disagreement with statements spelling out possible priorities for cleanup and risk reductions. The sixth section elicited the usual respondent sociodemographics.

The survey was self-administered using the computer by respondents recruited from the general population in four cities in Italy (Venice, Milan, Bari and Naples) in May 2005, for a total of 804 completed questionnaires. These cities were selected to ensure geographic representativeness and because each has one or more sites on the National Priorities List.[8] The sample was stratified by age, with an equal number of respondents in each of three broad age groups (25-44, 45-54, 55-65), and was comprised of a roughly equal number of men and women. We did not expect all respondents to be familiar with computers, so we made sure that two interviewers were present at the survey facilities at all times to welcome the respondents, introduce the survey to them and provide assistance if requested.

4. The Model.

[8] The chemical and oil refining complex of Porto Marghera in the Venice hinterland is probably the most egregious contaminated site on the NPL, with soils, groundwater and Lagoon sediments contaminated by polycyclic aromatic hydrocarbons (PAHs), heavy metals and many other pollutants. The former Fibronit complex, an asbestos-processing facility, is located in downtown Bari, while the NPL site in Naples is a closed steel mill. Milan, as the center of a large industrial area, has several NPL sites.

In our questionnaire, we ask the following question: "Suppose there were two public programs for cleaning up contaminated sites. These two programs differ for technology and completion time. Program A saves 100 lives now. Program B saves X lives in Y years. If the cost of the two program were the same, which would you choose, A or B?" X and Y were varied to the respondents (X= 150, 200, 300, 400; Y = 10, 20, 30, 40, 45).[9]

Let D* be the discount rate that makes the two programs result in the same number of discounted lives saved. In other words, assuming constant exponential discounting, D*=(-1/Y)*(ln(100/X)). In our survey, D* ranged from less than 1 percent to about 14%. The respondent should choose program A if his or her own discount rate, D_i, is greater than D*, B if D_i is less than D*, and should be indifferent between the two programs if D_i is equal to D*.

We assume that D_i is i.i.d. normal with mean μ_D and variance σ_D^2. Our sample is thus a mix of binary and continuous observations, and the log likelihood function is

$$(1) \qquad \ln L = \sum_{i \in choose\ \mathrm{A}} \ln \Phi\left(\frac{\mu_D}{\sigma_D} - \frac{D_i^*}{\sigma_D}\right) + \sum_{i \in choose\ \mathrm{B}} \ln\left[1 - \Phi\left(\frac{\mu_D}{\sigma_D} - \frac{D_i^*}{\sigma_D}\right)\right] + \sum_{i \in indifferent} \ln \phi\left(\frac{\mu_D}{\sigma_D} - \frac{D_i^*}{\sigma_D}\right)$$

where $\Phi(\cdot)$ and $\phi(\cdot)$ are the cdf and pdf of the standard normal distribution, respectively.

We wish to investigate whether there is heterogeneity in the discount rate across respondents, and to do so we amend equation (1) to allow the discount rate to depend

---

[9] These time horizons are consistent with latency times assumed, for example, by the US Environmental Protection Agency. A 20-year lag between now and the time of the risk reduction was considered by the EPA Science Advisory Board when examining the maximum contaminant limit allowable for arsenic in drinking water (see www.house.gov/science/ets/oct04/ets_charter_100401.htm, accessed 22 January, 2006). The EPA's model for arsenic in water, which is adapted from a smoking cessation lag model where the majority of the reduction in the risk of cancer is incurred within the first five years following cessation (US Environmental Protection Agency, 2003), is also compatible with shorter lags.

systematically on individual characteristics and/or attitudes about saving lives and time preferences expressed elsewhere in the survey. Specifically, we replace μ_D with

(2) $$\mu_{Di} = \mathbf{x}_i \boldsymbol{\beta},$$

where $\mathbf{x}_i$ is a vector of individual characteristics and/or variables capturing attitudes.

As mentioned, equations (1) and (2) assume constant exponential discounting, in that the discount rate may vary across individuals, but does not change over time within an individual. To investigate whether this assumption is borne out in the data, we fit separate equations (1) for each of the independent subsamples that were assigned a given time horizon (T=10, 20, 30, 40 and 45). To accommodate discount rates that change over time, we re-estimate equation (1) for the full sample after introducing two additional amendments, namely that

(3) $$\mu_{Di} = \mathbf{x}_i \boldsymbol{\beta} + T_i \gamma,$$

where T is the time horizon presented to respondent i, or

(4) $$\mu_{Di} = \mathbf{x}_i \boldsymbol{\beta} + \mathbf{H}_i \boldsymbol{\delta},$$

where **H** is a vector of dummies capturing the time horizon.

Finally, we fit a statistical model that posits hyperbolic discounting. We use the one-parameter hyperbolic discount function proposed by Mazur (1987), which is formulated as D(t)=1/(1+kt), where t is time and k is unknown constant which we wish to estimate. This implies that a respondent will choose to save the 100 lives now if his or her own k_i exceeds k*, the constant that makes the respondent indifferent between present and future lives saved, which is equal to (1/T)(100/X-1). Again, the respondent will prefer to save X lives T years from now if k_i is less than k*, and will be indifferent between the two options k_i is roughly equal to k*.

If k_i is normal with mean μ_k and variance σ_k^2, the contribution to the likelihood is

$$\text{(5)} \qquad \ln L = \sum_{i \in choose\,\mathrm{A}} \ln \Phi\left(\frac{\mu_k}{\sigma_k} - \frac{k_i^*}{\sigma_k}\right) + \sum_{i \in choose\,\mathrm{B}} \ln\left[1 - \Phi\left(\frac{\mu_k}{\sigma_k} - \frac{k_i^*}{\sigma_k}\right)\right] + \sum_{i \in indifferent} \ln \phi\left(\frac{\mu_k}{\sigma_k} - \frac{k_i^*}{\sigma_k}\right)$$

5. The Data

Descriptive statistics of the respondents are displayed in table 1. Our sample is well-balanced in terms of gender, and its distribution by age is consistent with the sampling plan. The average age is 47. The average annual household income is approximately €27,000, which is close to, but slightly lower than, the national average (€29,483, Banca d'Italia, 2006). Almost 50% of our sample has a high school diploma and 13.43% has a college degree or higher education. Comparison with population statistics reveals that our sample has a larger share of persons with high school diploma than the population, but is similar to the population in terms of share of persons with college degree or post-graduate education.

Table 1: Descriptive statistics of the respondents (N=804)

VARIABLE	DESCRIPTION	MEAN	STAND. DEVN.	MIN	MAX
Male	Dummy equal to 1 if the respondent is a male	0.51	0.50	0	1
Age	Respondent age	47.02	11.25	25	65
Married	Dummy equal to 1 if married	0.73	0.44	0	1
age2534	Respondent is aged 25-34	0.19	0.39	0	1
age3544	Respondent is aged 35-34	0.18	0.38	0	1
age4554	Respondent is aged 45-54	0.29	0.46	0	1
age55plus	Respondent is aged 55 or older	0.34	0.47	0	1
Collegedegree	Dummy equal to 1 if respondent has a college degree or post-graduate education	0.13	0.34	0	1
Household size	Number of household members	3.26	1.17	1	8
Kids15	Dummy equal to 1 if respondent has children of ages ≤15	0.28	0.45	0	1
Household income (€/year)	Take-home household income	26,955	16,872	5,000	100,000

Regarding their familiarity with contaminated sites, table 2 shows that 90% of the respondents stated that they had heard about contaminated sites before. Most of these persons reported that they learned about contaminated sites by watching the news on television. Forty-three percent of the sample indicated that they are aware of contaminated sites near their homes or workplaces. Almost 80% of the respondents were acquainted with the concept of cleanup, and 37% stated that they were personally aware of previously contaminated sites that had been subsequently cleaned up.

Table 2: Knowledge of contaminated sites. N=804.

Variable	Description	Percent of the sample
HEARD	Respondent has heard about contaminated sites before	90.04
KNOWSITE	Respondent is aware of a contaminated site near home or the workplace	43.16
HEARBONI	Respondent has heard about cleanup of contaminated sites before	79.98
KNOWBONI	Respondent is aware of a contaminated site that has been cleaned up	36.70

In table 3 we report the respondents' views of possible priorities for contaminated site policies, answers to debriefing questions, and other factors that might affect their preferences for remediation and time preference for lives saved. As show in table 3, almost 89% of the respondent stated that it is "very important" to them personally to reduce the human health risks posed by contaminated sites. Only 7% of the respondents indicated that they only thought of future generations when asked to make tradeoffs between size of risk reductions, their timing and permanence, and their cost (in the conjoint choice experiment part of the questionnaire).

Fully 40% of the sample strongly agreed that cleanups should take place, even if their benefits are experienced only 30 years from now, and 80% expressed strong agreement with the statement that cleanups should be as permanent as possible, even if they cost more.[10] Finally, about 30% of the sample reported that a family member has or has had cancer. We interpret familiarity with cancer as a proxy for concern about this illness.

[10] See Turvani et al. (2007) for descriptive statistics of the responses to other questions in the questionnaire.

Table 3. Opinions on contaminated sites policies and concern about mortality risks. N=804.

Variable	**Description**	**Percent of the sample**
Impexpos	Respondent deems it very important to reduce the adverse effects on human health of hazardous wastes	88.93
Solofut	Respondent thought only of future generations when answered conjoint choice questions	7.21
Futben	Favorable to cleanup even if its benefits are experienced 30 or more years from now	40.55
Durat	Respondent strongly agrees that remediation should be as permanent as possible even it costs more	79.60
Famcancer	Respondent's family members have had cancer	29.98

6. Estimation Results.

When asked to choose between saving lives 100 now and X lives in the future, most people (80%, or 626 individuals) preferred the program that saves lives now, 14.7% (115 people) preferred the one that saves lives in the future, and 5.2% (41 people) were indifferent between the two.[11] Using a "clean" sample of 782 respondents,[12] and assuming constant exponential discounting, we estimate μ_D (see equation (1)) to be equal to 12.36%, while σ_D is pegged at 0.0870 (see table 4). The latter indicates that there is substantial heterogeneity among people's individual discount rates.

However, as shown in table 5, we find only modest evidence that D_i depends in predictable ways on observable individual characteristics of the respondents. It is sometimes argued that people's discount rates are lower if they have small children, but

[11] Cropper et al. (1991) report that in their combined Maryland and Washington, DC area samples, fully 40% of the respondent chose the program that saves lives now, even when the number of lives to be saved in the future was very large.
[12] We obtained this sample after dropping those respondents who received a version of the questionnaire where a typographical error appeared in the risk reduction of one of the conjoint choice questions.

the coefficient on KIDS15, the variable denoting whether the respondent has children of age up to 15 years, is insignificant. Likewise, gender and marital status are not significantly associated with a respondent's implicit discount rate. The discount rate is, however, 2.44 points lower among the 45-54 year-olds. This effect, however, is barely statistically significant at the 10% level.

We has expected that knowledge of contaminated sites (KNOWSITE), strong concern about the adverse health effects of exposure to contaminants (IMPEXP), and even having a family member with cancer (FAMCANCER) to be systematically related to the discount rate, but these expectations are not borne out in the data. The covariate with the strongest association with the discount rate for lives saved is FUTBEN, a dummy denoting whether the respondent is in favor of remediation even when its benefits are incurred many years into the future. Respondents who pronounced themselves in favor of remediation with benefits in the distant future have discount rates that are about 2 percentage points lower for those of the others, while being favorable to permanent remediation, even if it is more expensive (dummy DURAT), and sole concern about future generation (SOLFUT), have no effect on discount rates.

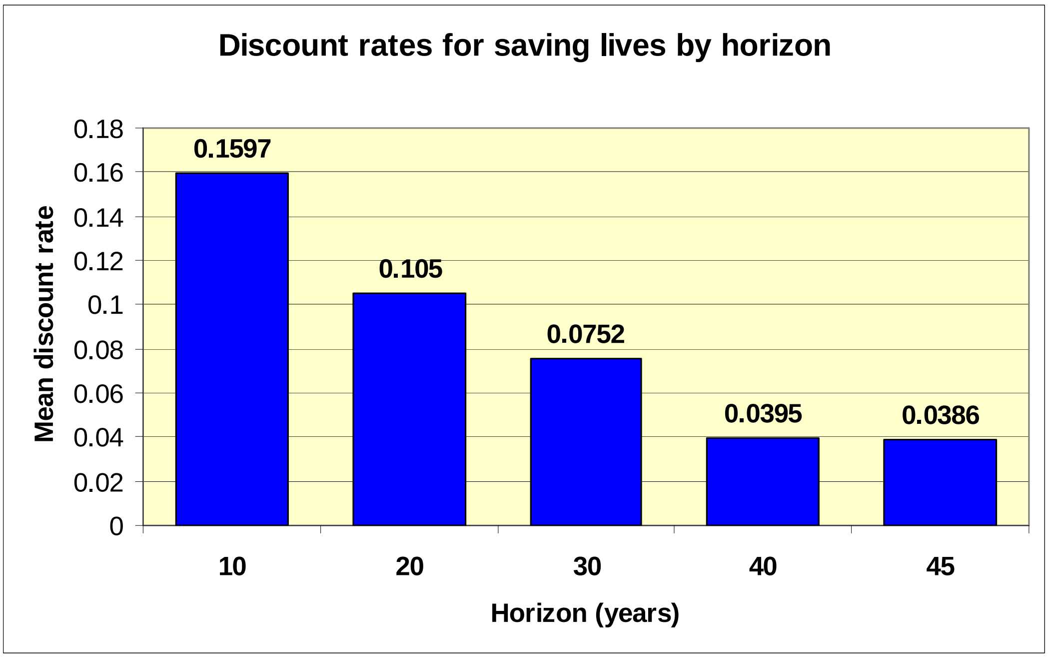
Table 4. Continuous-Discrete model of discount rates for lives saved. Model with no covariates. N=782.

variable	**coefficient**	**se**	**t stat**
Intercept	0.1236	0.0087	14.2069
Scale	0.087	0.0085	10.23529

Table 5. Continuous-Discrete model of discount rates for lives saved. Model with covariates. N=782.

variable	Description	coefficient	t stat
Intercept		0.1323	6.819
kids15	Respondent has children of age ≤ 15 (dummy)	0.0027	0.231
married	Respondent is married (dummy)	-0.0004	-0.033
durat	Respondent strongly agrees that remediation should be as permanent as possible even if it costs more (dummy)	0.0004	0.034
futben	Respondent is favorable to cleanup even if its benefits are experienced 30 or more years from now (dummy)	-0.0230	-2.396
solofuture	Respondent thought of future generations when making money-future risk reduction tradeoffs (dummy)	-0.0122	-0.709
male	Respondent is a male (dummy)	-0.0041	-0.446
age55plus	Respondent's age ≥ 55 (dummy)	0.0013	0.084
age4554	Respondent's age 45-54 (dummy)	-0.0244	-1.638
age3544	Respondent's age 35-44 (dummy)	-0.0061	-0.379
famcancer	Respondent has a family member who has or has had cancer (dummy)	0.0062	0.608
impexp	Respondent deems it very important to reduce the adverse health effects of hazardous wastes (dummy)	0.0136	0.919
Knowsite	Respondent knows of a contaminated site near home or work (dummy)	-0.0059	-0.634
Scale	Standard deviation of the discount rate	0.0862	10.141

Figure 1.



We also wish to test whether people's responses are indeed consistent with constant exponential discounting. Figure 1, which displays the (constant exponential) discount rates estimated after we separate the data into the 5 subsamples that received T=10, 20, 30, 40 and 45, respectively, suggests otherwise. Clearly, people's implicit discount rate are higher for shorter time horizons and lower for more distant time horizons, ranging from 16% for T=10 to less than 4% for T≥40. Indeed, the discount rate profile flattens out at T=40 and higher. These results confirm earlier claims and findings by, for example, Thaler and Lowenstein (1989) and Cropper et al. (1992).[13] (The full estimation results for each subsample with different Ts are displayed in table A.1 in the Appendix. That table shows that both the mean and standard deviation of the discount rate fall with the length of the horizon.)

We therefore turn to our hyperbolic discounting model. Estimation results are reported in table 6. The estimate of μ_k is 0.2504. Figure 2 displays a comparison between the hyperbolic and constant exponential discount functions estimated from the survey responses. The discount factors are roughly the same—0.285 for the hyperbolic model and 0.290 for constant exponential discounting—for T=10, which is the shortest time horizon we used. Saving 1000 lives in 10 years is thus equivalent to saving 290 now. Saving 1000 lives in 15 years would be worth 156 lives now with constant exponential discounting and 210 with hyperbolic discounting. For time horizons of 25 and 30 years, the difference would be even more dramatic, the present-value figures being 138 and 117 for hyperbolic discounting, and only 45 and 13, respectively, with constant exponential

---

[13] See Viscusi and Huber (2006) for recent evidence of hyperbolic discounting in tradeoffs between money and water quality.

discounting. The constant exponential discount factor declines much faster thereafter, to the point that saving 1000 lives in 40 years is worth 90 lives now under hyperbolic discounting, and only 7 with constant exponential discounting. (Horizons shorter than 10 years are thus out-of-sample predictions, and should be interpreted with caution.)

Table 6. Continuous-Discrete model of discount rates for lives saved. Model with no covariates. Hyperbolic discounting model. N=782.

	coefficient	t stat
intercept	0.2504	13.31915
scale	0.1866	10.25275
log L	-317.23	

Figure 2. Comparison between constant exponential and hyperbolic discount functions estimated from the survey responses.

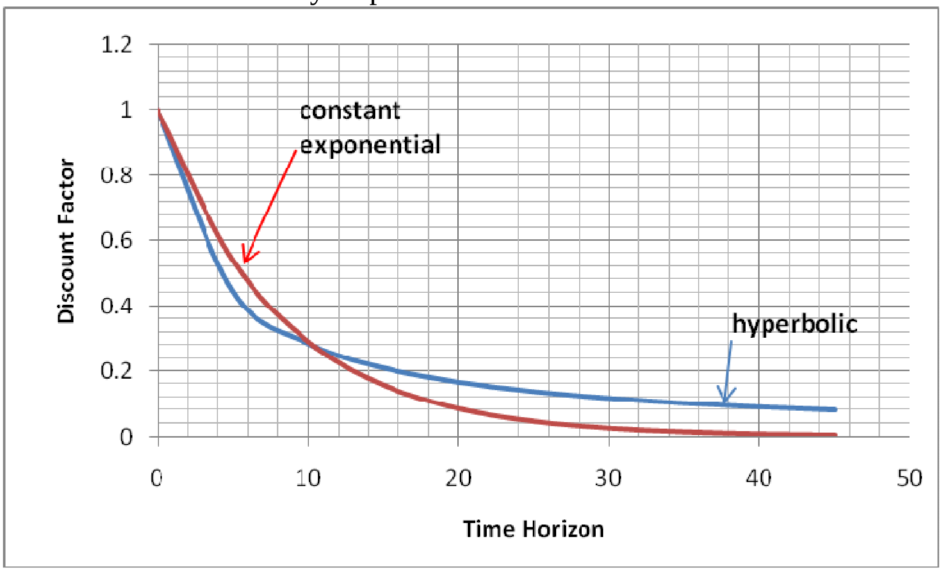


Table 7. Continuous-Discrete model of discount rates for lives saved. Model with covariates. Hyperbolic discounting model. N=782.

Variable	Description	coefficient	t stat
Intercept		0.2696	6.496
kids15	Respondent has children of age ≤ 15 (dummy)	0.0071	0.285
married	Respondent is married (dummy)	0.001	0.039
Durat	Respondent strongly agrees that remediation should be as permanent as possible even if it costs more (dummy)	0.0005	0.020
Futben	Respondent is favorable to cleanup even if its benefits are experienced 30 or more years from now (dummy)	-0.0497	-2.412
solofuture	Respondent thought of future generations when making money-future risk reduction tradeoffs (dummy)	-0.028	-0.767
Male	Respondent is a male (dummy)	-0.0081	-0.413
age55plus	Respondent's age ≥ 55 (dummy)	0.0045	0.135
age4554	Respondent's age 45-54 (dummy)	-0.0542	-1.710
age3544	Respondent's age 35-44 (dummy)	-0.0144	-0.420
famcancer	Respondent has a family member who has or has had cancer (dummy)	0.0168	0.771
Impexp	Respondent deems it very important to reduce the adverse health effects of hazardous wastes (dummy)	0.025	0.791
Knowsite	Respondent knows of a contaminated site near home or work (dummy)	-0.0134	-0.673
Scale	Standard deviation of the discount rate	0.1837	10.149
log L		-309.908	

When we include covariates, the results are qualitatively similar to those of the corresponding constant exponential model. None of the individual characteristics of the respondents is strongly associated with the discount factor. Persons in the 45-54 age group are somewhat more patient than others, but this effect is statistically significant only at the 10% level. Again, responses are internally consistent, in the sense that those persons who state that they favor remediation policies that produce benefits (risk reductions) in the future also make choices that imply lower discount rates.

5. Discussion and Conclusions

We have used choice questions to obtain information about the rate of time preferences for saving lives in the hazardous waste site context. This kind of question asks an individual to think as a social decision maker. We have found that the responses to our questions imply a constant exponential discount rate of 12%. This rate is substantially higher than those routinely used by Western government in policy analyses (4-10% in the US and 4% in the European Union). We find evidence of considerable heterogeneity in the discount rates, but little evidence that such variation is systematically related to observable individual characteristics of the respondents or attitude towards future and/or more permanent risk reduction (and cleanup).

What's perhaps most surprising is that neither better educated individuals nor respondents with small children seem to be more future oriented than the others. In the case of the effect of children, it is possible that this lack of an association reflects a mix of individual types, some of whom might care more for their children *when they are young*.

Finally, when we allow for the discount rate to vary over the time horizon, we find that it decreases with the length of the time horizon, ranging from 16% for T=10 to less than 4% for T≥40. This suggests that discount rate are not constant over time, and is suggestive of hyperbolic discounting. When we indeed fit a hyperbolic discounting model, we find that its predicts a value of the discount function similar to that of the constant discounting model for T=10, but the two are sharply different for T>10. Saving 1000 lives in 45 years is worth 90 lives now with hyperbolic discounting, and only 7 under constant exponential discounting. That people exhibit discount rates that decline with the time horizon is consistent with the idea that individuals are impatient for latent environmentally-induced harm that they (and the community that they live in) might experience when they are still alive, whereas their ability to distinguish between time horizons is much less sharp when the time horizon is long enough to imply a different generation (Revesz, 1999).

The implications of these findings for hazardous waste remediation policies can be illustrated by calculating the cost per life saved under two alternate remediation scenarios for a 43-hectare contaminated area within the Marghera National Priority List (NPL) site in Italy. In this area—a former industrial waste dump now owned by the City of Venice—soil and groundwater are heavily contaminated with polyaromatic hydrocarbons, heavy metals, and other toxicants (Patassini et al., 2003, 2005). We restrict attention to contaminated soil and two possible remedies: capping, and soil excavation and removal. The latter is, clearly, a permanent remedy, while for the former we assume that the cap would last for 10 years. The pre-remediation excess lifetime cancer risk is estimated to be 4.78E-03, which we convert into an excess lifetime risk of dying of 3.35E-03 (see Alberini et al., 2007) for an exposed population of 30,000.

Following Patassini et al. (2005) we assume that soil excavation and removal, which cost €45.589 million, would reduce risks by 95%; we further assume that the life saving benefits delivered by this remedy would begin in 2 years and last for 45, which means that the annual risk reduction would be 4.54E-05. By contrast, a cap would cost €5 million and be just as effective over its lifetime, but last only 10 years, after which mortality risks would return to the pre-remediation levels.

Under these assumptions, if lives are not discounted, there would be a total of 61.3 lives saved under the soil excavation and removal scenario and 13.62 under the cap scenario. The cost per life saved by these remedies would be €0.744 million and €0.367 million, respectively. Clearly, the cap is more cost-effective than the soil excavation option, but in both cases the cost per life saved is modest when compared to that of many regulatory programs (see, for example, Morrall, 2003).

Using constant exponential discounting, we calculate that there would 8.57 present-valued lives saved by soil excavation and 6.11 present-value lives saved by the cap. Given the cost of each remedy, the cost per life saved would be €5.316 million for soil excavation and €0.872 million for capping. Discounting lives has therefore increased by gap in cost-effectiveness between the two remediation plans, making soil excavation more than five times as costly as the cap on a per-life saved basis.

With hyperbolic discounting, we would get 9.08 present-value lives saved by excavation and 4.54 lives saved by capping, with cost-effectiveness figures of €5.016 million and €1.171 million, respectively. Hyperbolic discounting would thus make excavation slighly more favorable, but still much less cost-effective than capping.

We conclude by noting that in our survey questionnaire hazardous waste was linked primarily with future cancer outcomes, and that other environmental exposures—such as those to air polllution or heavy metals—have been associated with different long-term health outcomes, i.e., cardiovascular risks. One interesting question is whether people’s rates of time preference depend on the nature of the health risks, and on the degree of “dread” and other attributes of the risk itself (Hammitt and Liu, 2004). Our study, however, was not designed specifically to answer this question, which we leave to future research.

References

Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici (2004), "Metodologie, Tecniche e Procedure per il Supporto degli Interventi di Valorizzazione dei Siti Inquinati," Rome, June.

Alberini, Anna, Maureen L. 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, Maureen Cropper, Alan Krupnick and Nathalie Simon (2006), "Willingness to Pay for Risk Reduction: Does Latency Matter?" *Journal of Risk and Uncertainty*, 32, 231-245.

Alberini, Anna, Stefania Tonin, Margherita Turvani, e Aline Chiabai (2007), "Paying for Permanence: Public Preferences for Contaminated Site Cleanup", *Journal of Risk and Uncertainty*, 34(2), 155-178.

Alberini, Anna and Aline Chiabai (2007), "Discount Rates in Risk versus Money and Risk versus Risk Tradeoffs" *Risk Analysis*, 27(2), 483–498.

Banca d'Italia (2006), *I bilanci delle famiglie italiane nell'anno 2004*, Supplementi al Bollettino statistico anno XVI n. 7, Rome, January.

Benzion, Uri, Amnon Rapaport and Joseph Yagil (1989), "Discount Rates Inferred from Decisions: An Experimental Study," *Management Science*, 35(3), 270-284.

Blomquist, Glenn C., Mark C. Berger, John P. Hoehn (1988), "New Estimates of Quality of Life in Urban Areas," *American Economic Review*, 32(6), 1213-1226.

Carson, Richard T. and Robert C. Mitchell (2006), "Public Preferences toward Environmental Risks: The Case of Trihalomethanes," in Anna Alberini and James Kahn (eds.), Handbook on Contingent Valuation, Cheltenham, UK: Edward Elgar Publishing Ltd.

Cerruto, Salvo Renato (2007), "La bonifica dei siti contaminati: disciplina previgente, disciplina attuale e prospettive di riforma", *Rivista giuridica dell'ambiente*, 2, 259- 288.

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

Cropper, Maureen L. and Paul R. Portney (1990), "Discounting and the Evaluation of Life Saving Programs," *Journal of Risk and Uncertainty*, 3, 369-379.

Cropper, Maureen L., Sema K. Aydede and Paul R. Portney (1991), “Discounting Human Lives,” *American Journal of Agricultural Economics*, 73(5), 1410-1415.

Cropper, Maureen L., Sema K. Aydede and Paul R. Portney (1992), “Rates of Time Preference for Saving Lives,” *American Journal of Agricultural Economics*, 82(2), 469-472.

Cropper, Maureen L. and David Laibson (1999), “The Implications of Hyperbolic Discounting for Project Evaluation” in eds. John Weyant and Paul R. Portney Discounting and Intergenerational Equity, Washington: Resources for the Future.

Dasgupta, Partha and Eric Maskin (2005), “Uncertainty and Hyperbolic Discounting”, *The American Economic Review*, 95(4), 1290-1299.

Dell’Anno, Paolo (2006), “Bonifiche e recupero funzionale dei siti contaminati”, Il *Diritto dell'economia*, 4, 697 – 740.

Dijkgraaf, Elbert and Vollebergh, Herman R.J. (2004), "Burn or bury? A social cost comparison of final waste disposal methods", *Ecological Economics*, 50(3-4), 233-247.

Frederick, Shane, George Lowenstein, and T. O’Donoghue (2002), “Time discounting and Time Preference: A Critical Review,” *Journal of Economic Literature*, XL, 351-401 (June).

Frederick, Shane, (2006), “Valuing future life and future lives: A framework for understanding discounting, *Journal of Economic Psychology*, 27, 667–680.

Hahn, Robert (2005), “In Defense of the Economic Analysis of Regulation,” AEI-Brookings Joint Center for Regulatory Studies, Washington, DC.

Hamilton, James T. and W. Kip Viscusi (1995), “The Magnitude and Policy Implications of Health Risks from Hazardous Waste Sites,” in Richard L. Reversz and Richard B. Stewart (eds.), *Analyzing Superfund. Economics, Science and Law*, Washington, DC: Resources for the Future.

Hammitt, James K. and Jin-Tan Liu (2004), “Effects of Disease Type and Latency on the Value of Mortality Risk,” *The Journal of Risk and Uncertainty*, 28(1), 73-95.

Harrison, Glenn H., Morten I Lau, and Melonie B. Williams (2002), “Estimating Individual Discount Rates in Denmark: A Field Experiment,” *American Economic Review*, 92(5), 1606-1617.

Harvey, Charles M. (1994), “The Reasonableness of Non-constant Discounting,” *Journal* of *Public Economics*, 53 (1), 31-51.

Hausman, Jerry A. (1979), “Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables,” *Bell Journal of Economics*, 10(1), 33-54

Horowitz, John K. and Richard T. Carson (1990), “Discounting Statistical Lives,” *Journal of Risk and Uncertainty*, 3, 403-413.

Jenkins, Robin, Nicole Owens, and Lanelle B. Wiggins (2001), “Valuing Reduced Risks to Children: The Case of Bicycle Helmets,” *Contemporary Economic Policy*, 19(4), 397-408.

Johannesson, Magnus and Per-Olov Johansson (1996), “To be or Not to Be, That is the Question: An Empirical Study of the WTP for Increased Life Expectancy at an Advanced Age,” *Journal of Risk and Uncertainty*, 13, 163-174.

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.

Karp, Larry (2005), “Global warming and hyperbolic discounting”, *Journal of Public Economics*, 89, 261–282.

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 Survey of Ontario Residents,” *Journal of Risk and Uncertainty*, 24, 161-186.

Laibson, D. (1997), “Golden Eggs and Hyperbolic Discounting,” *Quarterly Journal of Economics*, 112(2), 443-477.

Legambiente (2005), “La chimera delle bonifiche”, http://www.verdenero.it/doc/La_chimera_delle_bonifiche.pdf (accessed April 30, 2008).

Lowenstein, George, and D. Prelec (1992), “Anomalies in the Intertemporal Choice: Evidence and an Interpretation,” Quarterly Journal of Economics, 107(2), 572-597.

Mazur, James E. (1987), “An Adjustment Procedure for Studying Delayed Reinforcement”, in the *Effect of Delay and Intervening Events on Reinforcement Value*, Michael L. Commons, James E. Mazur, John A. Nevin and Howard Rachlin, eds. Hillsdale, NJ: Erlbaum.

Moore, Michael J. and W. Kip Viscusi (1990), “Models for Estimating Discount Rates for Long-Term Health Risks Using Labor Market Data,” *The Journal of Risk and Uncertainty*, 3, 381-401.

Morrall, John F. III (2003), “Saving Lives: A Review of the Record,” *The Journal of Risk and Uncertainty*, 27(3), 221–237.

Patassini, Domenico, Paola Cossettini, Enrico De Polignol, Markus Hedorfer, and Enrico Rinaldi (2003), “El.Gi.R.A. Una procedura di aiuto alla conoscenza nelle aree di bonifica di Porto Marghera (Venezia),” paper presented at a FEEM seminar, http://www.iuav.it/Didattica1/pagine-web/facolt--di2/Domenico-P/ricerca/Bonifiche-/slide_ELGIRA.pdf (accessed July 11, 2008)

Patassini, Domenico, Paola Cossettini, Enrico De Polignol, Markus Hedorfer, and Enrico Rinaldi (2005), “ELGIRA: Support System for Knowledge Building and Evaluation in Brownfield Redevelopment”, in CORILA (ed.), *Scientific Research and Safeguarding of Venice, Research Programme 2001-2003*, Volume III, CORILA, Venice, 5-20.

Polinder, Suzanne, Willem Jan Meerding, Job van Exel and Werner Brouwer, 2005, Societal Discounting of Health Effects in Cost-Effectiveness Analyses. The Influence of Life Expectancy, *Pharmacoeconomics*, 23(8), pp 791-802.

Redden, Joseph P. (2007), Hyperbolic Discounting, in Roy F. Baumeister and Kathleen D. Vohs (eds.), *Encyclopedia of Social Psychology*, Thousand Oaks, CA: Sage Publications.

Revesz, Richard L. and Richard B. Stewart (1995), “The Superfund Debate,” in Revesz, Richard L. and Richard B. Stewart (eds.), *Analyzing Superfund: Economics, Science, and Law*, Washington, DC: Resources for the Future.

Revesz, Richard L. (1999), “Environmental Regulation, Cost-Benefit Analysis, and the Discounting of Human Lives,” Berkeley Program in Law & Economics, Working Paper Series. Paper 134, March, available at http://repositories.cdlib.org/blewp/art134 (accessed July 17, 2008).

Ruderman, Henry, Mark Lveine and James McMahon (1987), “Energy-Efficiency Choice in the Purchase of Residential Appliances,” in W. Kempton and M. Neiman (eds.), *Energy Efficiency: Perspectives on Individual Behavior*, Washington, DC: American Council for an Energy Efficient Economy.

Shane, Frederick, George Lowenstein, and Ted O’Donoghue (2002), “Time Discounting and Time Preference: A Critical Review,” *Journal of Economic Literature*, XL, 351-401

Sunstein, Cass R., Arden Rowell (2007), “On discounting Regulatory Benefits: Risk, Money, and Intergenerational Equity,” The *University of Chicago Law Review*, 4(1), 171-208.

Thaler, Richard and George Lowenstein (1989), "Intertemporal Choice," *Journal of Economic Perspectives*, 3, 181-193.

Turvani, Margherita, Aline Chiabai, Anna Alberini, and Stefania Tonin (2007), "Public Policies for Contaminated Site Cleanup: The Opinions of the Italian Public", FEEM Working Paper, 11.2007, Milan, Italy, January.

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

US General Accounting Office (1997), Superfund: State Voluntary Programs Provide Incentives to Encourage Cleanups, GAO/RCED-97-66, Washington, DC, April.

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

Viscusi, W. Kip and Joel Huber (2006), "Hyperbolic Discounting of Environmental Quality," NBER Working Paper No. W11935, Cambridge, MA.

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.

Warner, John T., and Saul Pleeter (2001), "The Personal Discount Rate: Evidence from Military Downsizing Programs," *American Economic Review*, 91(1), 33-53.

Appendix A.

Table A.1. Estimation results. Separate models for each subsample.

	t=10		t=20		t=30		t=40		t=45	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
discount rate	0.1597	0.0186	0.105	0.0166	0.0752	0.013	0.0395	0.0035	0.0386	0.0048
Scale	0.1034	0.0232	0.0623	0.0161	0.0414	0.0109	0.0181	0.0032	0.0186	0.0048

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:
http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm
http://www.ssrn.com/link/feem.html
http://www.repec.org
http://agecon.lib.umn.edu
http://www.bepress.com/feem/

NOTE DI LAVORO PUBLISHED IN 2009

SD	1.2009	Michael Hoel: Bush Meets Hotelling: Effects of Improved Renewable Energy Technology on Greenhouse Gas Emissions
SD	2.2009	Abay Mulatu, Reyer Gerlagh, Dan Rigby and Ada Wossink: Environmental Regulation and Industry Location
SD	3.2009	Anna Alberini, Stefania Tonin and Margherita Turvani: Rates of Time Preferences for Saving Lives in the Hazardous Waste Site Context