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Measures of Mortality Risks[1]

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Abstract

Different risks of death are not equivalent because of differences in timing. This paper develops measures of mortality risks that recognize the probability of death, the duration of life lost, and the role of discounting. These adjustments lead to a substantial reordering of the major causes of death. Recognition of duration-related issues explains much of the public's misperception of mortality risk probabilities, which may reflect duration-related concerns rather than biases in risk beliefs. Our estimates suggest that in forming their risk beliefs the public discounts years of life lost at a rate from 3.3–12.4 percent. Standardization of lifetimes at risk also alters the relative efficacy of regulatory policies for which we provide a variety of cost-effectiveness measures.

Key words: risk perception, mortality risks, value of life, rates of time preference

JEL Classification: J-17

A fundamental building block of empirical and policy discussions of mortality risks is some assessment of the magnitude of the risk that is present. For the most part, discussions focus on the probability of death. A substantial literature, however, has documented that the appropriate matter of concern should be some quantity-adjusted measure of the life lost.[2] This paper develops several different measures of mortality risk and explores their implications for several major areas of concern in the mortality risk literature.

The starting point for thinking about mortality risk is to develop some assessment of what the mortality risk is for the individual. What are the major causes of death and how is the assessment of these causes dependent on the mortality risk measure? When people think about the various risks they face, do different aspects of the mortality risk enter, or is it simply the risk probability? From a societal standpoint, what are the major risks to be targeted and how does the relative cost-effectiveness of different policy options vary after recognizing this class of concerns?

The analysis here will incorporate three components. First, we will recognize the probability of death at different ages. Second, we will incorporate a recognition of the duration of remaining life at risk. In doing so we will incorporate the role of discounting.

Third, we will also take into account any lag time between the time of exposure to the risk and the time when the adverse health effect occurs.

Section 1 develops these different measures of mortality risk. To do so we use information on mortality risk probabilities assessed for different causes of death and link this information to data on lost life expectancy and related aspects of the timing of these events. We develop rank orders of the different causes of death as well as continuous quantitative measures. These refinements do not simply result in a rescaling of death risk probabilities, but in many instances generate a dramatic shift in the mortality risk ranking.

Section 2 incorporates this information in an empirical analysis of the public's perception of different mortality risks. Inclusion of the discounted expected years of life lost in the analysis of the public's perception of risk probabilities greatly increases the explanatory power of the perception model. This result suggests that biases in risk perception may stem in part from the public's recognition of the duration of life lost in rating different risks rather than focusing simply on the probability alone. As a part of this inquiry we also present a new approach to estimating implicit rates of time preference for years of life when people are assessing risks.

Section 3 incorporates these measures in a review of the cost per life saved and the cost per discounted year of life saved of a wide variety of government regulations. The primary implication of this examination is that adjusting for duration and timing issues enhances the relative cost-effectiveness of the most desirable government interventions and tends to decrease the relative cost-effectiveness of regulatory interventions that are less worthwhile.

Section 4 concludes the paper.

1. Quantifying mortality risks

1.1. Methodology

To quantify the magnitude of mortality risks, we will utilize three different empirical magnitudes that relate to the mortality risks. The first is the size of the probability of death. This probability affects people at different ages, but tabulations of risk probabilities make no adjustment for these differences. Thus, for a population of 200 million in which 200 six-year olds die from cause of death A and 200 seventy-year olds die from cause of death B, then the probability of death associated with each cause of death would be one in 1 million. Clearly the risks are quite different in terms of the magnitude of the human health loss.

The second component of the analysis is the remaining life expectancy. For a life expectancy at age six of seventy-one the lost life expectancy is sixty-five years. Similarly, for an average life expectancy at age seventy of fourteen years, the lost life expectancy of six years olds is over four times as great. The expected date of death is pushed out the longer one lives, though on less than a one-for-one basis.

The third aspect of the analysis is the role of discounting. Even in the case of acute accidents, the appropriate matter of economic concern is the discounted expected number of years of life lost, thus recognizing any rate of time preference the individual has with respect to different years of life.[3]

A fourth concern is the effect of deferred rather than immediate risks. For many health risk exposures, there is a lag before the mortality risk occurs. One would want to take this lag time into account when calculating the discounted expected number of years of life that are lost as assessed at the time one is making the risk taking decision.

More formally, the lost life expectancy, *LLE*, from an ailment is the mean average number of years of life expectancy lost per victim. We model *LLE*s for specific ailments using information comparing the age distribution of victims to those of the general population.

The model we use to estimate death statistics focuses upon a hypothetical sample of N_0 people born in period $t = 0$, and follows this population for $\bar{t}$ years, calculating the number of deaths suffered by the cohort for each of various ailments each year. During year t of the model, some number of the cohort, d_t, dies, with some smaller number d_{jt} of those deaths due to condition j. Given the overall population death rate for persons age t, r_t, the number of survivors at the end of any given period N_t is

$$N_t = N_0 \prod_{i=0}^{t} (1 - r_i). \tag{1}$$

Once the surviving populations for each period are known, the number of deaths expected from ailment j in period t, d_{jt}, is a straightforward multiplication of N_t by the death rate for the ailment for persons of age t, or

$$d_{jt} = r_{jt} N_t, \tag{2}$$

which can be written as

$$d_{jt} = r_{jt} N_0 \prod_{i=0}^{t} (1 - r_i). \tag{3}$$

The benefit of using the hypothetical cohort of newborns is that each person who dies in year t is known to be t years old at the time of death. The life expectancy tables produced in *Vital Statistics* provide information to determine the lost life expectancy, *LLE*, of an individual aged t, which we denote by l_t. The product $d_{jt} l_t$ is the number of expected life years lost due to deaths of individuals in year t due to condition j. The average lost life expectancy for victims of condition j, expressed as LLE_j, is calculated within the model as

$$LLE_j = \frac{\sum_{i=0}^{\bar{t}} d_{ji} l_i}{\sum_{i=0}^{\bar{t}} d_{ji}} \tag{4}$$

The numerator of the term on the right side of Equation 4 sums the $d_{jt} l_t$ terms over all $\bar{t}$ years of the model. It yields the total lost years of life for the cohort due to the measured condition. The denominator of this expression sums all the fatalities due to condition j

measured within the model. The expression as a whole yields the expected years of life lost per victim of the condition.

The expected years of life lost, $E(YLL)$, is a very similar statistic. However, it measures the average expected years of life lost per member of the population, rather than the average expected years of life lost per victim of the condition. More formally, this expression takes the form

$$E(YLL)_j = \frac{\sum_{i=0}^{\bar{t}} d_{ji}\, l_i}{\sum_{i=0}^{\bar{t}} d_i}. \tag{5}$$

The numerator in Equation 5 for $E(YLL)_j$ remains the same as in Equation 4. However, the denominator in Equation 5 counts the total number of deaths for the duration of the model rather than just the deaths attributable to condition j in Equation 4. The $E(YLL)_j$ measure is analogous to calculating the amount by which overall population life expectancy would increase in the absence of any deaths due to a given ailment. The expected years of life lost is related to the LLE in that $E(YLL)$ is equal to the LLE times the lifetime probability of death from a given ailment.

Since individuals have positive rates of time preference with respect to years of life, we also estimate the discounted expected years of life lost for different ailments. Letting r denote the discount rate and p_j represent the lifetime probability of death from condition j, the discounted expected years of life lost, $DE(YLL)_j$, is given by

$$Discounted\ E(YLL)_j = p_j \cdot \frac{(1+r)^{LLE_j} - 1}{r(1+r)^{(LLE_j - 1)}}. \tag{6}$$

The latter term in Equation 6 calculates the years of additional life expectancy given immediate onset, discounting future years at an annual rate of r percent. That value can be thought of as a summation of LLE_j terms representing the discounted value of the n^{th} additional year of life. This amount, in turn, can be calculated as an infinite series of discounted years minus a similar series lagged LLE_j years. The value of the infinite series is

$$1 + (1+r)^{-1} + (1+r)^{-2} + \ldots = \frac{(1+r)}{r}, \tag{7}$$

where $r \neq 0$. Then the value of the discounted LLE_j becomes

$$\frac{(1+r)}{r} - \frac{(1+r)}{r(1+r)^{LLE_j}} = \frac{(1+r)^{LLE_j} - 1}{r(1+r)^{(LLE_j - 1)}}\ . \tag{8}$$

We will set the interest rate at a fixed value of 3 percent for these calculations, but subsequently we will estimate people's implicit rate of time preference.

Finally, for some illnesses there is a lag time before the effects occur. Cancer risks, for example, are not immediate. With a lifetime probability of death from condition j of p_j and a lag time of s years, which we will set at 10 years in most of the analysis below, the discounted expected years of life lost from a current exposure is given by

$$DE(YLL)_j \cdot (1 + r)^{-s} = p_j \cdot \frac{(1 + r)^{LLE_j} - 1}{r(1 + r)^{(LLE_j - 1)}} \cdot (1 + r)^{-s}. \tag{9}$$

The last term in Equation 9 simply discounts the expected years of life lost an additional s years to account for the deferral of the condition's onset.

Some risks are immediate, and others are deferred. To recognize this difference the calculations below utilize the *DE*(*YLL*) value for the no lag situation, and the lagged value of *DE*(*YLL*) when the risks are deferred. Because different risk measures are used in each case, we refer to this set of valuations as the "mixed" case.

1.2. Empirical implementation

For the calculations, we obtained our life expectancy data for persons aged 0 through 85 from *Vital Statistics of the United States*.[4] We extrapolated these life expectancy figures to age 100. We also obtained death rates for the overall population, and for many major medical ailments, for 11 age groups from *Vital Statistics*.[5] Death rates for many accidental causes of death, by age group, are from the 1993 edition of the National Safety Council's annual *Accident Facts* report. We made no attempt to scale death rates within the age groups, as the short ranges considered render the effects minor.[6] Due to the nature of the model, the population becomes asymptotic to zero, making some cutoff time period necessary to begin calculations. We set the maximum age, $\bar{t}$, for this model at 100 years. Approximately 2.8% of the hypothetical population survives to this age, but their omission does not significantly alter the *LLE* calculations.

To illustrate the workings of our approach, we provide estimates for the major causes of death. Tables 1 and 2 list the relevant death statistics for twelve major conditions, supplemented by our estimates generated within the computer model. The conditions represent the ten leading causes of death as reported in the *Vital Statistics of the United States*, plus perinatal conditions and congenital anomalies, which are major causes of death among the young, and result in large lost life expectancies.

The first column of statistics in Table 1 contains the lifetime probability of death associated with a condition, as measured by the proportion of the total fatalities from our model that can be attributed to the condition. The probabilities closely match the proportions of fatalities in a given year attributable to each cause of death after allowing for demographic changes in age distribution.

In addition to reporting the probability of death, Table 1 lists the lost life expectancy LLE_j and expected lost years of life $E(YLL)_j$ for each condition. The effects of implicit

Table 1. Mortality risk estimates for 12 conditions

		Lost Life Expectancy (*LLE*) and Expected Years of Life Lost (*E*(*YLL*))							
		Undiscounted		3%-discount		10-year lag		Mixed	
Condition	Probability of death	*LLE*	E(*YLL*)	*LLE*	E(*YLL*)	*LLE*	E(*YLL*)	*LLE*	E(*YLL*)
Overall deaths	0.9633	12.91	12.44	9.95	9.59	7.40	7.13		
Cardiovascular disease	0.4478	10.34	4.63	8.54	3.82	6.35	2.84	6.35	2.84
Neoplasms (cancer)	0.2184	14.39	3.14	11.22	2.45	8.35	1.82	8.35	1.82
Pneumonia/influenza	0.0415	8.94	0.37	7.39	0.31	5.50	0.23	7.39	0.31
Obstructive pulmonary conditions	0.0396	11.60	0.46	9.53	0.38	7.09	0.28	7.09	0.28
All accidents	0.0315	29.36	0.92	17.20	0.54	12.80	0.40	17.20	0.54
Diabetes	0.0214	12.82	0.28	10.19	0.22	7.58	0.16	7.58	0.16
Auto accidents	0.0142	37.19	0.53	20.86	0.30	15.52	0.22	20.86	0.30
Liver disease/cirrhosis	0.0099	20.38	0.20	14.70	0.15	10.94	0.11	10.94	0.11
Suicide	0.0099	30.87	0.31	18.79	0.19	13.98	0.14	18.79	0.19
Homicide	0.0068	43.46	0.30	23.68	0.16	17.62	0.12	23.68	0.16
Perinatal conditions	0.0045	75.37	0.34	30.63	0.14	22.79	0.10	30.63	0.14
Congenital anomalies	0.0037	57.54	0.21	25.44	0.10	18.93	0.07	25.44	0.10

Note: Lost Life Expectancies (LLE) and Expected Years of Life Lost (*E*(*YLL*)) calculations incorporate 3% annual discounting and 10-year lags for diseases which may not occur immediately after exposure to stimulus.

discounting of future payoffs are reflected in several ways.[7] Table 1 includes several measures of the discounted mortality losses. For a three percent discount rate and no lags, Table 1 presents both the discounted lost life expectancy as well as the discounted expected years of life lost. The next set of set of columns incorporates a ten-year lag before the risk effects become apparent. Such a lag assumption is appropriate for some deferred

Table 2. Rank orders of mortality risks for major conditions

	Probability of Death		Lost Life Expectancy		Expected Life Years Lost	
	Rank	Probability	Rank	*LLE*	Rank	*E*(*YLL*)
Cardiovascular disease	1	0.4478	12	6.35	1	2.84
Neoplasms (cancer)	2	0.2184	8	8.35	2	1.82
Pneumonia/influenza	3	0.0415	10	7.39	4	0.31
Obstructive pulmonary conditions	4	0.0396	11	7.09	6	0.28
All accidents	5	0.0315	6	17.20	3	0.54
Diabetes	6	0.0214	9	7.58	8	0.16
Auto accidents	7	0.0142	4	20.86	5	0.30
Liver disease/cirrhosis	8	0.0099	7	10.94	11	0.11
Suicide	9	0.0099	5	18.79	7	0.19
Homicide	10	0.0068	3	23.68	9	0.16
Perinatal conditions	11	0.0045	1	30.63	10	0.14
Congenital anomalies	12	0.0037	2	25.44	12	0.10

Note: Lost Life Expectancies (*LLE*) and Expected Years of Life Lost (*E*(*YLL*)) calculations incorporate 3% annual discounting and 10-year lags for diseases which may not occur immediately after exposure to stimulus.

risks, such as cancer, but not for others, such as accidents. The final pair of columns reports what we call the “mixed estimates” for both the discounted lost life expectancy as well as the discounted expected years of life lost.

The conditions associated with high probabilities of death also tend to have lower lost life expectancies. For example, cardiovascular disease has a high probability of death but a total life expectancy lost of 10.34 years. Homicides are much less likely to be a cause of death, with a probability of 0.0068, but the effects are more catastrophic with 43.46 years of life lost. After discounting, the lost life expectancy differences are dampened somewhat, but this effect is partially offset once the lag time for cardiovascular disease is recognized. However, because of the high overall probability of cardiovascular disease, the net results in the “mixed estimates” is that the discounted expected years of life lost is 2.84 for cardiovascular disease as opposed to 0.16 for homicides.

Table 2 excludes the overall deaths category and reports risks and rank order values for 11 major conditions. There is a strong inverse relationship between the rank of the lost life expectancy conditional upon death and the probability of death. Each of the top four causes of death is among the bottom five in terms of years of life lost per case (lost life expectancy, or *LLE*), while each of the four least likely causes of death is in the top five in terms of *LLE*. The effects of *LLE* upon the expected years of life lost are minor, with only liver disease/cirrhosis changing more than two spots in the rankings from the raw probabilities of death, but the dampening effect upon the range is noticeable. The ratio of the cardiovascular disease statistic to that of congenital anomalies drops from 121:1 to 28:1. That the expected years of life lost statistics have a smaller relative range than the raw probabilities of death is a result very similar to risk perception findings.

2. Public perceptions of mortality risks

2.1. Mortality risk estimates for a larger set of risks

The major focus of the mortality risk literature has been on individual risk beliefs. Much of this work has considered how people rate mortality risks. These risks are of particular consequence for people’s lives given the severity of the outcomes involved. In addition, there are well-established national levels for these risks, making it possible to judge whether the public’s perceptions are accurate. The focus here will be on assessed mortality risks for a wide variety of risk types, where we will extend the focus of our previous analysis to include a more diverse set of risks that have been the object of past studies of mortality risks. After developing these mortality risk measures, we will then explore the public’s perceptions of these risks and how recasting the risk measure that is used to judge the public’s perception of risk may account for much of the perceived bias in the character of risk beliefs.

Tables 3 and 4 reexamine the mortality risk patterns using a larger sample of conditions. Although this extension is intended largely to provide insight into past studies of risk perception, it also is useful in establishing the general character of the results. We based the replication/extension upon the 41 causes of death for which risk perceptions

Table 3. Mortality fact table for 29 conditions

Cause	Probability of death	Undiscounted *LLE*	Undiscounted *E*(*YLL*)	3%-discount *LLE*	3%-discount *E*(*YLL*)	10-year lag *LLE*	10-year lag *E*(*YLL*)	Mixed *LLE*	Mixed *E*(*YLL*)
All causes	0.9730	13.53	13.16	10.15	9.87	7.55	7.35		
All disease	0.9248	12.58	11.64	9.72	8.99	7.23	6.69	7.23	6.69
Heart disease	0.3496	10.56	3.69	8.69	3.04	6.47	2.26	6.47	2.26
All cancer	0.2184	14.39	3.14	11.22	2.45	8.35	1.82	8.35	1.82
All other diseases	0.0819	11.97	0.98	9.21	0.75	6.86	0.56	6.86	0.56
Stroke	0.0724	9.54	0.69	7.97	0.58	5.93	0.43	7.97	0.58
Lung cancer	0.0616	15.21	0.94	11.95	0.74	8.89	0.55	8.89	0.55
Stomach cancer	0.0539	13.05	0.70	10.43	0.56	7.76	0.42	7.76	0.42
All accidents	0.0315	29.36	0.92	17.20	0.54	12.80	0.40	17.20	0.54
Diabetes	0.0214	12.82	0.27	10.19	0.22	7.58	0.16	7.58	0.16
Breast cancer	0.0183	16.16	0.30	12.23	0.22	9.10	0.17	9.10	0.17
All other accidents	0.0173	22.93	0.40	14.20	0.25	10.57	0.18	14.20	0.25
Motor-vehicle accident	0.0142	37.19	0.53	20.86	0.30	15.52	0.22	20.86	0.30
Suicide	0.0099	30.87	0.31	18.79	0.19	13.98	0.14	18.79	0.19
Leukemia	0.0079	15.68	0.12	11.43	0.09	8.50	0.07	8.50	0.07
Emphysema	0.0070	12.13	0.09	9.99	0.07	7.44	0.05	7.44	0.05
Homicide	0.0068	43.46	0.30	23.68	0.16	17.62	0.12	23.68	0.16
Accidental falls	0.0056	12.47	0.07	9.59	0.05	7.13	0.04	9.59	0.05
Asthma	0.0020	17.61	0.03	12.53	0.02	9.33	0.02	9.33	0.02
Poisoning	0.0015	34.26	0.05	20.42	0.03	15.20	0.02	20.42	0.03
Fire and flames	0.0014	32.22	0.04	17.86	0.02	13.29	0.02	17.86	0.02
Drowning	0.0013	42.89	0.05	22.42	0.03	16.68	0.02	22.42	0.03
Tuberculosis	0.0007	17.17	0.01	12.44	0.00	9.25	0.00	9.25	0.01
Infectious hepatitis	0.0006	20.05	0.01	14.16	0.00	10.54	0.00	14.16	0.01
Firearms	0.0004	45.93	0.02	24.10	0.00	17.93	0.00	24.10	0.01
Appendicitis	0.0002	13.54	0.00	10.56	0.00	7.86	0.00	10.56	0.00
Pregnancy/childbirth/abortion	0.0000	48.84	0.00	26.03	0.00	19.37	0.00	26.03	0.00
Syphilis	0.0000	34.86	0.00	16.78	0.00	12.49	0.00	12.49	0.00
Measles	0.0000	73.63	0.00	30.44	0.00	22.65	0.00	30.44	0.00

Note: Lost Life Expectancies (*LLE*) and Expected Years of Life Lost (*E*(*YLL*)) calculations incorporate 3% annual discounting and 10-year lags for diseases which may not occur immediately after exposure to stimulus.

were measured by Lichtenstein et al. (1978). Specific numbers of fatalities were not available from our sources for fourteen of the conditions, and they were not included in the sample. We added two additional categories—“all other accidents” and “all other diseases”—to correct for this loss.[8]

Table 3 displays the various mortality statistics. Included in this table is information pertaining to the probability of death, the lost life expectancy, and expected years of life lost. Accidents, for example, involve an annual probability of death of 0.03, with 29.36 years of life lost on average by each accident victim. The expected years of life lost for any individual is the product of these two terms, or 0.92 expected years of life lost. The next pair of columns presents the lost life expectancy figures after discounting at a 3% rate of interest. All accidents, for example, lead to 17.2 discounted lost life years, with a 0.54

Table 4. Rank orders of death measures for 29 conditions

	Deaths per 100,000		Lost Life Expectancy		Expected Years of Life Lost	
Cause	Rank	Deaths	Rank	*LLE*	Rank	*E*(*YLL*)
All causes	1	97299.5	21	13.53	1	13.16
All disease	2	92483.4	24	12.58	2	11.64
Heart disease	3	34956.3	28	10.56	3	3.69
All cancer	4	21839.7	19	14.39	4	3.14
All other diseases	5	8188.6	27	11.97	5	0.98
Stroke	6	7238.9	29	9.54	9	0.69
Lung cancer	7	6159.3	18	15.21	6	0.94
Stomach cancer	8	5388.4	22	13.05	8	0.70
All accidents	9	3149.1	11	29.36	7	0.92
Diabetes	10	2142.8	23	12.82	15	0.27
Breast cancer	11	1830.0	16	16.16	14	0.30
All other accidents	12	1727.6	12	22.93	11	0.40
Motor-vehicle accident	13	1421.0	6	37.19	10	0.53
Suicide	14	990.1	10	30.87	12	0.31
Leukemia	15	790.0	17	15.68	16	0.12
Emphysema	16	702.1	26	12.13	17	0.09
Homicide	17	681.7	4	43.46	13	0.30
Accidental falls	18	558.8	25	12.47	18	0.07
Asthma	19	196.4	14	17.61	22	0.03
Poisoning	20	151.7	8	34.26	20	0.05
Fire and flames	21	135.5	9	32.22	21	0.04
Drowning	22	127.5	5	42.89	19	0.05
Tuberculosis	23	74.7	15	17.17	24	0.01
Infectious hepatitis	24	60.6	13	20.05	25	0.01
Firearms	25	40.6	3	45.93	23	0.02
Appendicitis	26	17.4	20	13.54	27	0.00
Pregnancy/childbirth/abortion	27	8.7	2	48.84	26	0.00
Syphilis	28	1.5	7	34.86	29	0.00
Measles	29	0.8	1	73.63	28	0.00

Note: Lost Life Expectancies (*LLE*) and Expected Years of Life Lost (*E*(*YLL*)) calculations utilize a 3% annual discount rate and 10-year lags for non-immediate causes of death.

discounted expected years of life lost once one takes into account the low probability that an accident will occur. The next pair of columns in Table 3 presents similar discounted life year calculations assuming a 10-year lag before the adverse event occurs from the time of the risk exposure. This kind of lag assumption is only pertinent in the case of longer term diseases, not acute accidents. To make this adjustment, the final pair of columns that we label the “mixed” approach assumes that there is no time lag for the immediate risks, but there is a 10-year time lag for the longer term risks, such as cancer. One can also undertake similar kinds of sensitivity test using time lags of two decades or more if that is believed to be appropriate. The results here are intended to be generally illustrative of likely patterns of influence rather than suggest that there is precisely a ten-year lag in the longer term risk exposure instances.

The summary categories of all causes of death and all diseases head the rankings with minor causes of death such as appendicitis being near the bottom of the table. Heart disease and cancer are the most prominent causes of death based on the probability of death, whereas all accidents rank ninth and homicides rank seventeenth. Different rankings appear based on the lost life expectancy associated with these deaths. Heart disease drops to 28th and all cases of cancer drop to 19th, whereas motor-vehicle accidents are 6th in importance and homicides are 4th. More generally, the leading causes of death in terms of probability often rank near the bottom of the table in terms of expected life lost, whereas the low probability risks often involve substantial lost life expectancy. A more general characterization in terms of the types of events involved is that acute accidental events or immediate deaths tend to involve much greater loss of life than do health outcomes that may arise after physical deterioration or with a long time lag of risk exposures.

The final column in Table 4 reflects the combined influence of the probability of death and the amount of lost life expectancy. These figures are strongly correlated with the probability of death rankings. Most of the shifts in the rankings tend to be relatively minor as, for example, diabetes ranks 10th in terms of the probability of death and 15th in terms of the expected years of life lost.

Examination of the rank orders in Table 4 bolsters the character of the findings of Table 2. Seven of the top ten causes of death are in the bottom ten in terms of *LLE* (and nine of the ten are in the bottom twelve), while the ten least likely causes of death listed include seven of the ten conditions associated with largest lost life expectancies. While the dampening of the range is not as apparent here as in Table 2 due to the large number of less consequential risks at the bottom of the table, the *LLEs* for the top and bottom ranked causes of death indicate that the range of values as measured by ratio of top to bottom shrinks by a factor of 5.4.

In Table 5 we report correlation results to explore further the strength of the relation-

Table 5. Correlations matrices for 41 conditions.

Correlation matrix:

	Total deaths	Mixed *E*(*YLL*)	Mixed *LLE*
Total deaths	1		
Mixed *E*(*YLL*)	0.973	1	
Mixed *LLE*	−0.291	−0.325	1

Rank correlations:

	Total deaths	Mixed *E*(*YLL*)	Mixed *LLE*
Total Deaths	1		
Mixed *E*(*YLL*)	0.432	1	
Mixed *LLE*	−0.288	−0.481	1

Note: Variables are defined as follows:
Total Deaths: Number of actual deaths (1978 data)
Mixed *E*(*YLL*): Discounted expected years of life lost, *E*(*YLL*), with 10–year lags added when appropriate.
Mixed *LLE*: Discounted lost life expectancy, *LLE*, with 10–year lags added when appropriate.

ships discussed above. In particular, we examine the relations among total deaths, discounted expected years of life lost, and discounted lost life expectancy. These findings suggest similar relationships among the three variables.

Both the correlation matrix and the Spearman rank correlations show that when fatalities (or fatality rates) are multiplied by *LLE* to obtain expected years of life lost, the resulting statistic is inversely related to *LLE* while remaining strongly and directly correlated with fatalities.

The compression of the range of magnitude in expected years of life lost compared with the probability of death is very similar in nature to the often-noted discrepancies between actual fatality rates and perceived fatality rates. This similarity may be at least partially attributable to implicit consideration of lost life expectancy resulting from each death when people are asked for estimates of the death probability. The general public is typically not familiar with the actual statistics for *LLE*, but they may have a general sense of the relative magnitudes of the numbers based on their general knowledge.

Deaths of younger people, particularly children, are especially tragic, and receive relatively more publicity. While many researchers have hypothesized that people's risk perceptions are directly influenced by what they read as well as upon what they've experienced personally (the concept is known as availability), this phenomenon is not necessarily inconsistent with rational Bayesian learning. This pattern of beliefs might also arise because subjects are mistakenly including weights for length of life lost per case in their likelihood estimations. If this is the case, then a more accurate evaluation of whether risk perceptions are biased should take into account both actual death risks and *LLE* rather than focusing on actual death risks alone.[9]

2.2. Statistical analysis of perceived and actual risks

To study the usefulness of *LLE* in predicting risk perceptions, we modeled the perceived numbers of annual fatalities resulting from all 41 conditions reported in Lichtenstein et al. (1978) using actual fatality data in conjunction with several alternative variants of the *LLE*.[10] This analysis does not rule out Bayesian interpretation of their results as in Viscusi (1992).

Panel A of Table 6 shows the control results. In this panel we regress the public's perception of the mortality risk against the actual total death risk level for each risk category. If the death total were divided by the population it would convert the death variable into a probability. Doing so would simply rescale all the coefficients. Panel B supplements this regression analysis with an interaction term involving the lost life expectancy and total deaths. Thus, this term is the analogue of the expected years of life lost statistic calculated earlier. Panel C presents regression results in which the lost life expectancy values are discounted and the pertinent lags are taken into account as part of the estimation process using a 3 percent discount rate.

The results in these panels suggest that increases in death risks for a category lead to higher risk perceptions, but that the amount of life lost and the discounted value of the years of life lost are consequential as well. The large intercept and the smaller-than-unity

Table 6. OLS regression results for motor-vehicle accident anchored judgments

	Coefficient (Standard error)		
Variable	Panel A No cross-products	Panel B Undiscounted *LLES*	Panel C "Mixed" *LLEs*
Constant	4912	1561	660
	(2497) *	(1307)	(1010)
Total Deaths	.046	−.304	−.362
	(.008)***	(.033)***	(.028)***
LLE × Total Deaths		.028	.057
		(.003)***	(.004)***
Adjusted R^2	.434	.854	.915

parameter estimate reflect the commonly observed overestimation of low probability risks and underestimation of high probability risks. The estimated total deaths coefficient of 0.046 in Panel A means that it takes approximately 22 actual fatalities to increase the perceived number of fatalities by 1. The equation in Panel A including actual deaths and a constant term explains only 43 percent of the variation in perceived deaths.

Although direct inclusion of *LLE* as a regressor is statistically significant, use of a term interacting the *LLE* with actual deaths resulted in superior estimates of risk perceptions. The ordinary least squares (OLS) model in Panel B of Table 6 explains over 85 percent of the variation in perceived number of deaths, with both regressors highly significant at the $\alpha = 0.001$ level. At the mean level of *LLE*, about 2.7 additional actual deaths result in perception of one more death. Combined with the positive intercept term, this result also implies that an overestimation of low probability risks and underestimation of high probability risks will occur, but it is decreased in magnitude.

It is well known among economists that people discount future outcomes. Future years should be no exception. If the reason for including *LLE* in the estimation model is to account for people subconsciously weighting by the tragedy involved with the death, the proper weights would also include consideration of discounting. Panel C of Table 6 reports the results using such weights using an assumed 3 percent discount rate for the "mixed" *LLE* cases. Again, both variables produce parameter estimates which are significant at the $\alpha = 0.001$ level, and the fit of the model is even better, now explaining over 91% of total variation in risk perceptions. For this model there is a ratio of 2.4 additional actual deaths to one additional perceived death at the mean adjusted *LLE*. Individual risk beliefs are almost 10 times as responsive to changes in actual risks than in the model in Panel A without any *LLE* term.

Table 7 echoes the analysis in Table 6 using Lichtenstein et al.'s other sample of fatality risk perceptions. Anchoring perceptions around a less common cause of death (electrocution, as opposed to motor-vehicle accidents) lowered the perceived numbers of deaths for all conditions, as predicted in previous literature. Otherwise, the regressions in all three panels produce results which echo those of Table 6 in all substantive ways.

Table 7. OLS regression results for electrocution-anchored judgments

	Coefficient (Standard error)		
Variable	Panel A No cross-products	Panel B Undiscounted *LLES*s	Panel C "Mixed" *LLE*s
Constant	3528 (2456)	168 (1208)	−657 (989)
Total Deaths	.054 (.008)***	−.297 (.031)***	−.348 (.027)***
LLE × Total Deaths		.026 (.003)***	.056 (.004)***
Adjusted R^2	.518	.890	.928

2.3. Estimates of implicit rates of time preference

Up to this juncture, the estimation has taken as given the value of the discount rate, which has been set equal to three percent. However, in thinking about risks people may in fact use a higher rate of discount for years of life. Past estimates in Moore and Viscusi (1988) and in Viscusi and Moore (1989) suggest that workers have a somewhat higher rate of discount than three percent when valuing job fatality risks. However, workers still have a discount rate in a plausible range.

The approach we will adopt here is to estimate the implicit rate of discount based on which discount rate minimizes the residual sum of squares in the risk perception equation. This is the same criterion that has been applied for estimating implicit rates of time preference based on labor market decisions and other contexts. In effect, we are adding another parameter to the model to be estimated—the discount rate. The difference here is that it is the risk perception analysis that is being used as the framework for approaching the discount rate issue.

In much the same vein, it is also possible to estimate the implicit perceived time lag for the deferred risks that respondents are taking into account when formulating their risk perceptions. This lag could be a decade, as we have assumed, or it could be some other period. Thus, the regression analysis below will optimize over both perceived discount rates and perceived time lags for deferred risks. For concreteness, we will also examine the case in which there is an assumed time lag of ten years before the health effects are manifested.

To do this, we first calculate the Actual Deaths X "Mixed" *LLE* variable to include both individual attitudes toward discounting and lag times before the onset of some conditions. Letting LLE_j be the lost life expectancy to victims of condition j, r be the discount rate, and s be the anticipated length of the delayed onset of a condition in years, we have

$$Actual\ Deaths \times \text{“}Mixed\text{”}\ LLE = Deaths \cdot \frac{(1 + r)^{LLE_j} - 1}{r(1 + r)^{(LLE_j - 1)}} \cdot (1 + r)^{-s}. \tag{10}$$

The middle term on the right side of Equation 10 calculates the value of the additional life expectancy given immediate onset in the same manner as in Equation 6. The final term discounts the years until the onset of the condition, and falls to unity for $s = 0$ so that the term does not affect immediate causes of death.

Adding consideration for the perceived lag time before condition onset greatly improves the explanatory power of the model, as one would expect from the addition of an implicit parameter. The best fit for motor-vehicle accident-anchored perceptions occurs with a 25-year lag and 4.1 percent discount rate, while the best fit for electrocution-anchored perceptions is with a 7-year lag and 12.4 percent discounting.[11] Discount rates with a 10-year lag are 10.8 percent for the motor vehicle-anchored sample and 8.8 percent for the electrocution-anchored sample. Estimates of the implicit lag time may not be robust since the explanatory power of the model was not very sensitive to the implicit lag time.

The regression equations summarized in Table 8 indicate an inverse relationship between lag time and the parameter estimate for the discount rate. This relationship arises due to the correlated traits of the major causes of death, which effectively divide the sample into two general categories. The first category of conditions includes those with high fatality rates, low values of LLE_j, and lag times before condition onset, while the other includes less common causes of death with immediate consequences and high

Table 8. Effects of Lag Time and Estimated Discount Rates

	Coefficient (Standard error)			
MVA-Anchored Perceptions Variable	No lag	7-year lag	10-year lag	25-year lag
Intercept	1561 (1307)	726.3 (932)	704.5 (913)	574.6 (891)
Actual deaths	−.304 (.033)	−.336 (.024)	−.249 (.018)	−.139 (.011)
Actual deaths X "Mixed" *LLE*	.029 (.003)	.146 (.009)	.101 (.006)	.049 (.003)
Estimated discount rate	0.0%	15.4%	10.8%	4.1%
$\bar{R}^2$	.854	.927	.930	.934
Electrocution-Anchored Perceptions				
Variable	No lag	7-year lag	10-year lag	25-year lag
Intercept	168.4 (1208)	−493.4 (811)	−551.9 (817)	−676.2 (882)
Actual deaths	−.297 (.031)	−.377 (.023)	−.276 (.018)	−.159 (.013)
Actual deaths X "Mixed" *LLE*	.029 (.003)	.126 (.007)	.009 (.005)	.045 (.003)
Estimated Discount Rate	0.0%	12.4%	8.8%	3.3%
$\bar{R}^2$	.890	.951	.951	.943

Note: Both non-intercept parameter estimates are always significant at the $\alpha = 0.001$ confidence level.

values of LLE_j. An increased lag time parameter disproportionately lowers the value of the cross-product variable for the former group of conditions. In order to minimize the amount these lagged observations must be altered to distinguish them from those of the latter group, the values of observations in the latter group are correspondingly increased relative to the group with shorter LLE_js by lowering the discount rate. The different estimated optimal parameters for lag and discount rate between the motor vehicle accident-anchored group and the electrocution-anchored group reflects the ability of the parameters to adjust to fit varying groups of perceptions.

3. Regulatory performance

A common measure of regulatory performance is the cost per statistical life saved by the regulatory policy. Regulations that impose costs in excess of $5 million per life saved are above the midpoint of the estimated implicit values of life of the individual with respect to their risk making decisions.[12]

These calculations include a variety of simplifications, not the least of which is that they treat all lives saved as being homogeneous. Lives with very short expected duration receive the same weight as lives saved at very early years. Ideally, one would want to adjust for the quantity of life that is being extended as a result of the government intervention. In the absence of information regarding the valuation of life at different ages, we will explore how at least taking into account the amount of life lost and the discounted amount of life lost will affect the cost per life saved statistics.

As a practical matter, the main effect is that policies that reduce accident risks to individuals in younger age groups will tend to save lives of longer length than policies directed at longer term illnesses, such as cancer. The net effect will be to enhance the attractiveness of accident prevention policies and reduce the relative economic performance of longer term risk prevention efforts. In performing this analysis the reference point will be lives saved through the prevention of automobile accidents, where the automobile fatality effects will serve as the numeraire for the subsequent calculations. There is a large variance in estimated costs per statistical life saved associated with various federal regulations. Cost-effectiveness measures for a series of regulations analyzed by the U.S. Office of Management and Budget appear in Table 9. For each of these regulations, the reported cost per life saved estimates based on 1990 dollars are listed in column 4 and adjusted for inflation in column 5.[13]

Most analyses of the cost per life saved do not recognize the differing durations of life at risk. We have supplemented those usual estimates with *LLE*-based calculations. In terms of cost per year of life saved (column 7), the imposed costs across regulations varies even more widely than has been estimated previously. A useful metric is to put the cost per life saved into automobile accident risk equivalents. Examined this way, each death prevented from an auto accident saves two and a half years of life for each year of life saved by preventing a cancer death.[14] The final column in Table 9 summarizes the motor-vehicle accident risk equivalents for the various types of lives saved. Cost per life saved figures normalized upon by the auto accident *LLE*, as in column 6, contain even greater variance

Table 9. Regulatory costs and cost-effectiveness in saving lives

Regulation	Year	Agency	Cost per death averted, millions of 1990 dollars	Cost per life saved, millions of 1990 dollars	Mixed *LLE* (in years)	Cost per normalized life saved, 1995 dollars	Cost per year of life saved, 1995 dollars	Ratio of mixed *LLE* to auto accident *LLE*
Unvented space heater ban	1980	CPSC	0.1	0.1	17.20	0.1	0.0	0.82
Aircraft cabin fire protection standard	1985	FAA	0.1	0.1	17.20	0.1	0.0	0.82
Seat belt/air bag	1984	NHTSA	0.1	0.1	20.86	0.1	0.0	1.00
Steering column protection standards	1967	NHTSA	0.1	0.1	20.86	0.1	0.0	1.00
Underground construction standards	1989	OSHA	0.1	0.1	17.20	0.1	0.0	0.82
Trihalomethane in drinking water	1979	EPA	0.2	0.2	8.35	0.6	0.0	0.40
Aircraft seat cushion flammability	1984	FAA	0.4	0.5	17.20	0.6	0.0	0.82
Alcohol and drug controls	1985	FRA	0.4	0.5	17.20	0.6	0.0	0.82
Auto fuel-system integrity	1975	NHTSA	0.4	0.5	20.86	0.5	0.0	1.00
Auto wheel rim servicing	1984	OSHA	0.4	0.5	17.20	0.6	0.0	0.82
Aircraft floor emergency lighting	1984	FAA	0.6	0.7	17.20	0.9	0.0	0.82
Concrete and masonry construction	1988	OSHA	0.6	0.7	17.20	0.9	0.0	0.82
Crane suspended personnel platform	1988	OSHA	0.7	0.8	17.20	1.0	0.1	0.82
Passive restraints for trucks and buses	1989	NHTSA	0.7	0.8	20.86	0.8	0.0	1.00
Auto side-impact standards	1990	NHTSA	0.8	1.0	20.86	1.0	0.1	1.00
Children's sleepwear flammability ban	1973	CPSC	0.8	1.0	17.20	1.2	0.1	0.82
Auto side door supports	1970	NHTSA	0.8	1.0	20.86	1.0	0.1	1.00
Low-altitude windshear equipment and training	1988	FAA	1.3	1.6	17.20	1.9	0.1	0.82
Metal mine electrical equipment standards	1970	MSHA	1.4	1.7	17.20	2.0	0.1	0.82
Trenching and excavation standards	1989	OSHA	1.5	1.8	17.20	2.2	0.1	0.82
Traffic alert and collision avoidance systems	1988	FAA	1.5	1.8	17.20	2.2	0.1	0.82
Hazard communication standard	1983	OSHA	1.6	1.9	8.35	4.8	0.2	0.40
Trucks, buses and MPV side-impact	1989	NHTSA	2.2	2.6	20.86	2.6	0.1	1.00
Grain dust explosion prevention standards	1987	OSHA	2.8	3.3	17.20	4.0	0.2	0.82
Rear lap/shoulder belts for autos	1989	NHTSA	3.2	3.8	20.86	3.8	0.2	1.00
Stds for radionuclides in uranium mines	1984	EPA	3.4	4.1	8.35	10.1	0.5	0.40
Benzene NESHAP (original: fugitive emissions)	1984	EPA	3.4	4.1	8.35	10.1	0.5	0.40
Ethylene dibromide in drinking water	1991	EPA	5.7	6.8	8.35	17.0	0.8	0.40
Benzene NESHAP (revised: coke by-products)	1988	EPA	6.1	7.3	8.35	18.1	0.9	0.40

Table 9. Continued

Regulation	Year	Agency	Cost per death averted, millions of 1990 dollars	Cost per life saved, millions of 1990 dollars	Mixed *LLE* (in years)	Cost per normalized life saved, 1995 dollars	Cost per year of life saved, 1995 dollars	Ratio of mixed *LLE* to auto accident *LLE*
Asbestos occupational exposure limit	1986	OSHA	74.0	88.1	8.35	220.1	10.6	0.40
Asbetos occupational exposure limit	1972	OSHA	8.3	9.9	8.35	24.7	1.2	0.40
Benzene occupational exposure limit	1987	OSHA	8.9	10.6	8.35	26.5	1.3	0.40
Electrical equipment in coal mines	1970	MSHA	9.2	11.0	17.20	13.3	0.6	0.82
Arsenic emission standards for glass plants	1986	EPA	13.5	16.1	8.35	40.2	1.9	0.40
Ethylene oxide occupational exposure limit	1984	OSHA	20.5	24.4	8.35	61.0	2.9	0.40
Arsenic/copper NESHAP	1986	EPA	23.0	27.4	8.35	68.4	3.3	0.40
Hazardous waste listing of petroleum refining sludge	1990	EPA	27.6	32.9	8.35	82.1	3.9	0.40
Cover/move uranium mill tailings (inactive)	1983	EPA	31.7	37.7	8.35	94.3	4.5	0.40
Benzene NESHAP (revised: transfer operations)	1990	EPA	32.9	39.2	8.35	97.9	4.7	0.40
Cover/move uranium mill tailings (active sites)	1983	EPA	45.0	53.6	8.35	133.8	6.4	0.40
Acrylonitrile occupational exposure limit	1978	OSHA	51.5	61.3	8.35	153.2	7.3	0.40
Coke ovens occupational exposure limit	1976	OSHA	63.5	75.6	8.35	188.9	9.1	0.40
Lockout/tagout	1989	OSHA	70.9	84.4	17.20	102.4	4.9	0.82
Arsenic occupational exposure limit	1978	OSHA	106.9	127.3	8.35	317.9	15.2	0.40
Asbestos ban	1989	EPA	110.7	131.8	8.35	329.2	15.8	0.40
Diethylstilbestrol (DES) cattlefeed ban	1979	FDA	124.8	148.6	8.35	371.2	17.8	0.40
Benzene NESHAP (revised: waste operations)	1990	EPA	168.2	200.2	8.35	500.2	24.0	0.40
1,2-Dichloropropane in drinking water	1991	EPA	653.0	777.4	8.35	1942.1	93.1	0.40
Hazardous waste land disposal ban	1988	EPA	4190.4	4988.7	8.35	12462.7	597.4	0.40
Municipal solid waste landfills	1988	EPA	19107.0	22746.8	8.35	56826.1	2724.2	0.40
Formaldehyde occupational exposure limit	1987	OSHA	86201.8	102622.8	8.35	256372.7	12290.2	0.40
Atrazine/alachlor in drinking water	1991	EPA	92069.7	109608.5	8.35	273824.4	13126.8	0.40
Hazardous waste listing for wood-preserving chemicals	1990	EPA	570000.0	6785822.0	8.35	16952364.9	812673.3	0.40

Source: Regulatory Program of the United States Government, April 1, 1991–March 31, 1992, p. 12, for raw data in first four columns and calculations by the authors for all remaining data.

than the already widely disparate cost per life saved calculations reported previously. This finding means that the less expensive regulations near the top of the table, which are predominantly associated with prevention of automobile and workplace accidents, are relatively even better regulatory "bargains" than were previously believed. The flip side of the coin is that the extremely expensive regulations near the bottom of the table, which are mostly targeted at preventing cancer, become even more costly.

Suppose that we take as our reference point that regulatory policies that impose a cost per normalized life saved in excess of $5 million fail a benefit-cost test. Under this criterion, the rear lap/shoulder belts for auto regulation passes a benefit-cost test, as do all regulations above it in the table. The only difference in terms of failing a benefit-cost test is that two EPA regulations—one for radionuclides in uranium mines and another for benzene—fail benefit-cost tests whereas previously they passed.

The small shift in policies across a benefit-cost threshold does not mean that the adjustments for these mortality effects is unimportant. Because most of the cost-effective risk regulations tend to be safety regulations that affect accidents, the mortality adjustments are not consequential for the beneficial regulations. However, for the regulations that are not cost-effective, making the adjustments makes these policies even worse performers than they would already appear to be. For example, the cost per life saved for the OSHA arsenic occupational exposure limit rises from $127 million per life to $318 million per normalized life. Other health-related regulations are affected similarly.

Boosting cost per life saved amounts to such exorbitant levels highlights the substantial inefficiency in government regulatory policy, which is even greater than previous estimates have suggested. Moreover, to the extent that there is a mortality risk loss due to profligate regulatory expenditures that could have been allocated to other health-enhancing efforts, such as private expenditures on medical care and other consumption items, then the dramatic escalation of the estimated cost per life saved amounts has broader implications for the deleterious consequences of the current regulatory approach.

4. Conclusion

This article developed various quantity-adjusted measures of mortality risks. These estimates reflect not only the probability of death and the duration of life lost, but they also capture the influence of discounting and time lags before the risk effects are apparent.

The influence of these adjustments was not simply one of rescaling the risk estimates along some new metric. The relative rankings of the risk changed. The broader characterization of the risk measures helps inform us of the character of the public's risk perceptions and accounts for much of the apparent biases in risk beliefs. Finally, the recognition of the quantity-related factors also alters the assessment of regulatory performance.

The point of departure for the analysis was the assessment of the mortality risk measure for a wide variety of causes of death. Both for the major causes of death as well as for a much more extensive listing of death risks there is a consistent pattern in which the causes of death that ranked very high in terms of the probability of death also had associated lost life expectancy values that tended to be lower than many low probability accident risks. Our estimates of the mortality risk measures recognize the combination of these influences as well as the effect of discounting of years of life and lag times before deferred risks become apparent.

The analysis of mortality risk perceptions suggested that focusing on death risk probabilities alone does not fully account for the factors that drive the public's risk beliefs. A particularly influential factor is that both the expected number of life years lost and the discounted expected number of life years lost were extremely influential in accounting for the level of the public's mortality risk assessments. Past studies of biases in risk beliefs may have overstated the extent of the public's misperception to the extent that individuals were incorporating recognition of the duration of life lost when making their mortality risk judgments. These factors were not only statistically significant, but they also contributed substantial additional explanatory power to the risk perception analysis. Nevertheless, the influence of availability biases and perhaps the extent of risk information available appear to be consequential as well. Mortality risk perception estimates are more consistent for common causes of death than for rare conditions or freak accidents. There may be greater underlying uncertainty and less information about risks that are rare events. Whereas people do not seem to be giving consistent risk responses for rare events, for well-known causes of death their perceptions are much more rational. These types of factors would be consistent with a rational learning model in which individual information is imperfect, but in which individuals tend to have more reliable risk judgments as the extent of the information they have about the risk increases.

A particularly novel implication of our results is that it permitted estimation of both the implicit rate of discount and the implicit time lag that individuals assume in thinking about mortality risks. If we assume that there is a ten–year time lag before there is a health loss from deferred health risks, such as cancer, then the estimated discount rate implicit in individuals risk perceptions is 10.8 percent for the motor vehicle-anchored sample and 8.8 percent for the electrocution-anchored sample. When optimizing also over the time lag that individuals perceive, the assessed time lag for the motor vehicle-anchored perceptions was twenty-five years, with a 4.1 percent discount rate, whereas it was seven years with a 12.4 percent discount rate for the electrocution-anchored perceptions. Estimates of the implicit time lag appear to be less robust than the estimates for the rate of discount because the results were not as sensitive to the extent of the time lag as they were to the choice of the discount rate.

Consideration of the duration of life lost also affects the assessment of regulatory performance. Because the most cost-effective government regulations tend to be those affecting accidents rather than illnesses, the quantity adjustments that we undertook broaden the disparity between the least cost-effective and the most cost-effective regulatory policies. The most cost-effective regulations, such as seatbelt requirements for automobiles, tend to save many more years of life per fatality prevented. The most costly government regulations directed at preventing cancer, for example, commonly target ailments that occur later in life and well after the initial exposure to the cause of the condition. The basic message of these explorations is that one cannot rely on the probability of death alone as a single summary statistic for judging mortality risks. The immediacy of the risk and the timing of the risk in the person's life also are fundamental determinants of how we should think about the risk and how both society and individuals should address these risks in their protective decisions.

Notes

1. This research was supported by a U.S. EPA cooperative agreement to Duke University. All responsibility for the contents rests with the authors.
2. See, for example, Zeckhauser and Shepard (1976), Viscusi and Moore (1989), and Moore and Viscusi (1988).
3. The probability and life expectancy components have been considered in some past studies, but discounting has not. See Cohen (1981, 1991), Cohen and Lee (1991), and McGinnis and Foege (1993).
4. *Vital Statistics*, Table 6-3. Expectation of Life at Single Years of Age, by Race and Sex: United States, 1990.
5. *Vital Statistics*, Table 1-10. Death Rates for 72 Selected Causes, by 10-year Age Groups, Race, and Sex: United States, 1990.
6. Due to the use of the same death rate for all years within an age group, the *LLEs* for ailments associated with deaths later in life will be slightly overestimated, and those for causes of death which predominantly strike the young will be underestimated. These biases will be minor, as the wide distribution of *LLEs* in the accompanying tables demonstrate.
7. The lags are only included in those instances where delayed effects are possible. Whereas it may take years of poor diet and exercise habits before consequences develop, it is possible people's perceptions of the risk of cardiovascular disease are implicitly discounted by the time lag. Similar lagging of the risk of auto accidents is clearly unreasonable.
8. Sources for fatality data were the *Vital Statistics of the United States* and the National Safety Council's *Accident Facts*.
9. Even if the availability hypothesis is more valid, the possibility exists that *LLE* is a useful proxy for availability in instances where media coverage variables are somehow inadequate.
10. As in Lichtenstein et al. (1978), the same models were also estimated using the square of the number of deaths, to account for non-linearities in perceptions. The results of these models were not substantially different from those reported, and are omitted for brevity.
11. Models using 5-year and 30-year lag times were also estimated and optimized, the 7-year and 25-year lags offer the best fit for the electrocution-anchored and MVA-anchored perceptions, respectively.
12. See Viscusi (1992).
13. Inflation adjustment performed using CPI, drawn from *Statistical Abstract of the United States*. Viscusi (1992, 1993) and Breyer (1993) provide more extensive discussions of these regulations.
14. After allowing for 3% discounting and a 10-year lag for cancer onset.

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