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Estimating Fatalities Induced by the Economic Costs of Regulations

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Abstract

Regulatory costs are paid by individuals, which leaves them with less disposable income. Since individuals on average use additional income to make their lives safer and healthier, the regulatory costs lead to higher mortality risks and fatalities. Based on data from the National Longitudinal Mortality Study relating income to the risk of dying, approximately each $5 million of regulatory cost induces a fatality if costs are borne equally among the public. If costs are borne proportional to income, approximately $11.5 million in regulatory costs induces a fatality. Cost-induced fatalities disproportionally burden the poor and minorities, particularly blacks.

Key words: mortality risks, induced risks, regulatory fatalities

JEL Classification: J17

Billions of our dollars are spent annually in the U.S. to reduce life-threatening risks. Some billions are spent directly by the government, but numerous other billions are spent because of government regulations on individuals and industry. The regulated risks include those due to auto travel, air travel, air and water pollution, food and drugs, producing and using products, working, medical care, construction, our homes; basically everything.

To reduce the risks calculated to avoid one fatality, the cost to Americans is sometimes greater than $1 billion (Lutter and Morrall, 1994). To reduce the risks calculated to extend one life by one year, numerous governmental regulations require Americans to spend over $100 million (Tengs et al., 1995).

Should the government spend such massive sums if the calculated reduction of fatalities is small? Would it be better not to spend the taxpayers' money on the less effective regulations? The evidence shows that people with additional income spend their own money in ways that lower their mortality risks (Duleep, 1986b; Williams, 1990; Graham, Hung-Chang, and Evans, 1992; Chapman and Hariharan, 1994). Thus, the economic costs of regulations increase mortality risks which leads to fatalities (Wildavsky, 1979, 1980).

A key question is, "How much regulatory expenditure leads to one fatality?" The model developed in this paper suggests that between $5 million and $14 million of 1991 dollars induces one fatality.[1]

This article extends previous work (Keeney, 1990) in several ways:

1. The relationship between mortality risk and income is determined from longitudinal data (rather than cross-section data) based on the U.S. National Longitudinal Mortality Study of over 550,000 people.
2. The allocations of regulatory costs to individuals include a case with a luxury tax that places a higher percentage of the costs on higher income individuals (over $50,000 annually.)
3. Mortality implications are calculated separately for different racial groups and different income groups.
4. The stability of the relationship between regulatory expenditures and induced fatalities over the period from 1960 to the present is examined.

1. A model of cost-induced fatalities

The basic model used to estimate cost-induced fatalities is adapted from the original model developed in Keeney (1990). It addresses the situation where the total cost of a regulation is felt in a single year and where the monetary costs of that regulation are redistributed as they were charged to the individuals and society (i.e., there is no change in the distribution of income). The model, which uses the income measure of annual family income before taxes, has three fundamental components:

1. $r(x)$ = the annual probability of death for an individual with income x.
2. $f(x)$ = the distribution for the annual income of individuals prior to paying for the costs of the regulation.
3. $c(x)$ = the relative one-time cost of the regulation to individuals with different incomes.

1.1 Annual mortality risk

The first component was developed using data from two main sources: Kitagawa and Hauser (1973) and Frerichs et al. (1984). Both sources provide information suggesting that an exponential curve as shown in figure 1 can be used to relate annual mortality risk and income. This exponentially decreasing curve has three intuitively appealing properties: (a) the mortality risk increases as income decreases; (b) the mortality risk increases due to a specific income reduction are greater at lower income levels; and (c) the effect of income on mortality risk is relatively insignificant at high income levels.

A function representation for $r(x)$ with these properties is

$$r(x) = ae^{-bx} + d, \tag{1}$$

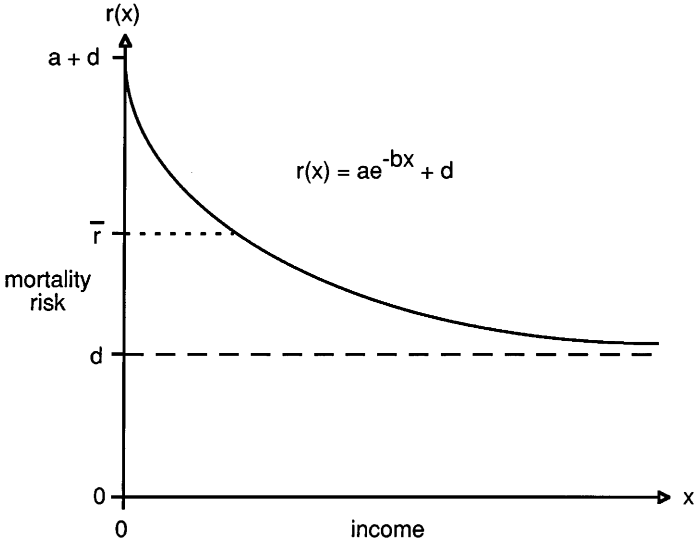

Figure 1. Model for the annual mortality risk.

where a, b, and d are positive constants and x represents income. If x is very large, then $r(x) = d$, so d can be thought of as the mortality risk of the wealthy or the residual mortality risk that is not reduced with additional income. When $x = 0$, then $r(x) = a + d$, which is the highest mortality risk. The constant a is the amount of mortality risk that can be influenced by income. The constant b, which has no simple interpretation, concerns the range of income over which there is an influence on mortality. The average mortality risk, labeled $\bar{r}$ in figure 1, lies between mortality risks d and $(a + d)$.

1.2 Distribution of annual income

The second component of the model specifies the number of households with annual income in various ranges. The *Statistical Abstract of the United States* (Bureau of the Census, 1993), defined the eight income groups in table 1 and the percentage p_i, $i = 1,\ldots, 8$, of a population group (e.g., whites) with each range of income. The number of people in a population group is defined as N. I assume that each individual in income groups 1 through 7 has the income x_i in the middle of the range. For group 8 with income above \$75,000, the assumed income x_8 was calculated so that the average income $\bar{x}$ given by

$$\bar{x} = \sum_{i=1}^{8} x_i p_i \tag{2}$$

was equal to the average income of the population group given in the *Statistical Abstract of the United States*.

Table 1. The model for distribution of income

Income group	Income range	Assumed income = x	Percentage of population
1	Under \$5,000	x_1 = \$2,500	p_1
2	\$5,000–\$9,999	x_2 = \$7,500	p_2
3	\$10,000–\$14,999	x_3 = \$12,500	p_3
4	\$15,000–\$24,999	x_4 = \$20,000	p_4
5	\$25,000–\$34,999	x_5 = \$30,000	p_5
6	\$35,000–\$49,999	x_6 = \$42,500	p_6
7	\$50,000–\$74,999	x_7 = \$62,500	p_7
8	\$75,000 plus	x_8 = \$104,350	p_8

Assigning the same income to individuals within an income group has no significant effect on the calculations of fatalities induced by regulatory costs. The assumption leads to a slight underestimation of the fatalities relative to spreading the distribution of incomes within an income group.

1.3 Individual cost of regulation

For different regulations, the costs may be differentially borne among individuals in society. The allocation of these costs to individuals depends on the complex workings of our economy and intermediaries (e.g., firms, government agencies) in the process. Thus, to get a feeling for the implications of different allocations of costs, the three relationships illustrated in figure 2 are examined in specific models. The relative costs in figure 2a are equal for all individuals regardless of income. In figure 2b, relative costs are proportional

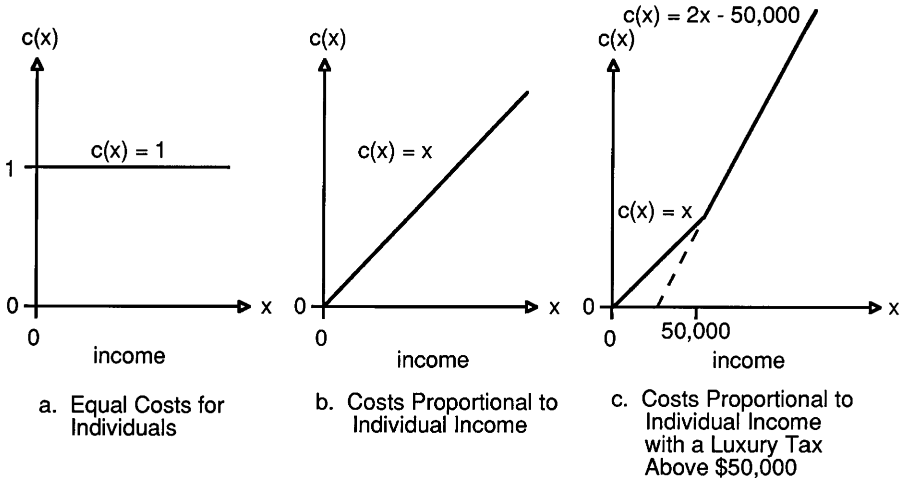

Figure 2. Relative regulation costs.

to incomes. Figure 2c represents the situation where higher income individuals pay a luxury tax; the regulatory cost as a proportion of income above \$50,000 is twice the rate for income up to \$50,000.

From the relative cost function $c(x)$ and the total cost of C_T, we calculate the absolute cost function $C(x)$ for individuals with income x. The relative individual cost necessarily relates to the absolute individual cost by a constant that we call k, thus

$$C(x) = kc(x). \tag{3}$$

Also, the total cost C_T must equal the contributions of all individuals so

$$C_T = \sum_{i=1}^{8} [Np_i]\, kc(x_i) \tag{4}$$

which can be solved for k yielding

$$k = \frac{C_T}{N \sum_{i=1}^{8} p_i c(x_i)}. \tag{5}$$

Substituting (5) into (3) and using p_i from table 1 provides the absolute costs of a regulation for an individual of income x.

1.4 Fatalities induced by regulatory costs

Consider the statistical increase in mortality risk, denoted by $\Delta r(x, C(x))$, for an individual of income x who pays an additional regulatory cost $C(x)$. This increase in probability of dying in a year is

$$\Delta r(x, C(x)) = r(x - C(x)) - r(x), \tag{6}$$

where r is obtained from (1). The curve plotting Δr from (6) versus C for each original income level represents a dose-response curve for how the additional regulatory cost affects annual mortality risk. Because of the shape of r in (1), a fixed additional regulatory cost has a larger effect on poorer individuals as illustrated in Keeney (1990).

The total additional fatalities ΔF induced by a regulatory cost C_T is calculated by summing up the expected implications for all of the individuals. Thus,

$$\Delta F = \sum_{i=1}^{8} \Delta r(x_i, C(x_i))\, Np_i, \tag{7}$$

since $\Delta r(x_i, C(x_i))$ is the increase in risk for an individual in income group i and Np_i is the number of people in group i.

2. Specifying parameters for the model

The data used to calculate model parameters are presented in this section.

2.1 Annual mortality risk

The annual mortality risk information is taken from the National Longitudinal Mortality Study conducted by the National Institutes of Health using information from 1979 to 1985 (Rogot et al., 1992). The data I use, shown in table 2, are for individuals 25–64 years of age and are based on a total sample size of over 550,000 individuals.

The parameters for the mortality risk model (1) were determined by fitting a least-square regression to these data. To do this, income was first adjusted to 1991 dollars using the change in the consumer price index from 1980 to 1991. Based on the *Statistical Abstract of the United States* (table 755), this resulted in multiplying 1980 dollars by 1.655. The lowest income group then had an income range of 0 to (1.655) ($5,000) = $8,275 in 1991 dollars. The midpoint of each dollar range, namely $4,137 for the lowest income group, measured in thousands of dollars was used in the regression. For regression purposes, $75,000 (in 1980 dollars) which escalates to $124,125 was used as the point estimate for the highest income group in table 2. The annual mortality risks were calculated by multiplying the relative annual mortality risk times the average annual mortality risk of a group. For example, the annual mortality risk of the poorest income group for white males is (1.79) (0.00646) = 0.01156.

Table 2. Annual mortality risks of individuals aged 25–64 as a function of income

Family income (1980 $)	Relative annual mortality risk[a] White males	Black males	White females	Black females
Under $5,000	1.79	1.55	1.65	1.50
$5,000–$9,999	1.59	1.15	1.20	1.05
$10,000–$14,999	1.22	1.09	1.06	0.90
$15,000–$19,999	0.99	0.79	0.95	0.72
$20,000–$24,999	0.86	0.72	0.93	0.72
$25,000–$49,999	0.79	0.67	0.80	0.61
$50,000 plus	0.66	0.59	0.79	0.56
Average annual mortality risk	.00646	.01030	.00349	.00584

[a]The relative annual mortality risk is set to be 1.0 when the mortality risk equals the average annual mortality risk.

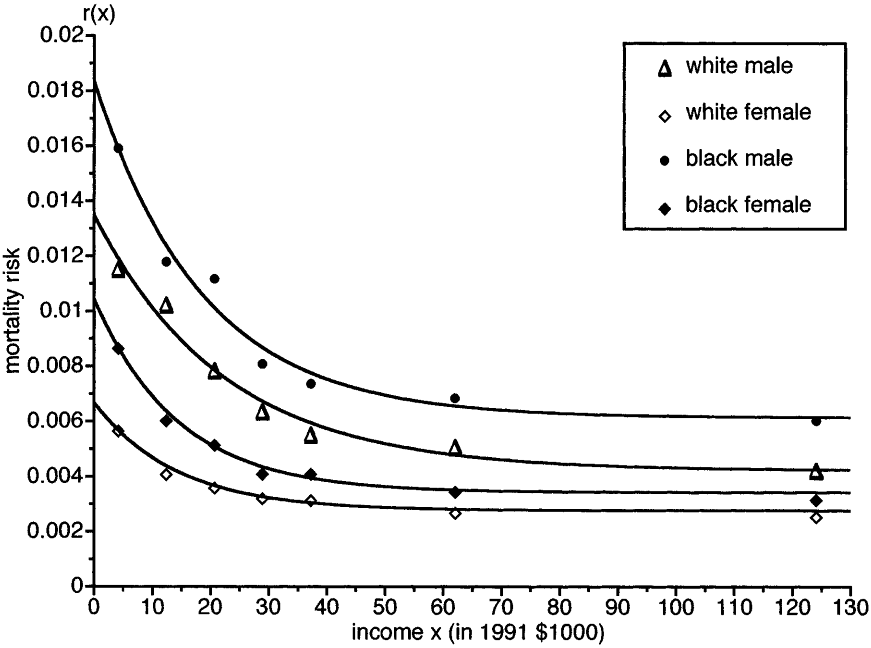

Figure 3. Model for the annual mortality risk fit to data.

The results of the least-square regression, along with the adjusted data, are illustrated in figure 3. The calculated parameters for the model are given in table 3 for the case where income is in thousands of dollars.

2.2 The distribution of annual income

The distribution of annual income is taken from the *Statistical Abstract of the United States* (table 713). The information used is in table 4, which shows the total number of white, black, and other households in 1991 and the percentage of each with particular incomes. The data for other households, defined as neither white nor black, were calcu-

Table 3. Parameters calculated for the annual mortality risk model[a]

Parameter	White males	Black males	White females	Black females
a	.00926	.0122	.00390	.00701
b	.0450	.0541	.0708	.0698
d	.00422	.00614	.00277	.00343

[a]The parameters in the annual mortality risk model (1) are calculated for 1991 dollars in thousands.

Table 4. Distribution of annual income for households in 1991

Income range (1980 $)	Percentage of population with income in range				
	White households	Black households	Other households	Total	Hispanic households
Under $5,000	3.7	12.6	6.0	4.8	6.8
$5,000–$9,999	9.1	18.2	7.3	10.1	13.9
$10,000–$14,999	9.1	11.6	9.4	9.4	12.1
$15,000–$24,999	17.3	18.2	17.2	17.4	21.6
$25,000–$34,999	15.4	13.8	14.9	15.2	15.8
$35,000–$49,999	17.9	13.4	15.3	17.3	14.8
$50,000–$74,999	16.3	8.4	16.8	15.4	10.0
$75,000 plus	11.2	3.7	13.5	10.4	5.0
Number of Households (1,000s)	81,675	11,083	2,911	95,669	6,379

lated as the total minus black and white households. Persons of Hispanic origin may be of any race and the data for Hispanic households in table 4 are directly from the *Statistical Abstract of the United States*.

2.3 Individual costs of regulations

The distribution of the individual costs of regulation across income groups was calculated assuming that the total cost of a regulation is $1 billion of 1991 dollars. Implications of different regulatory costs can be proportionally scaled from these results.

The cost to a household with specified income of the $1 billion regulation is given in table 5. These individual costs were calculated using the relative regulation costs in figure 2 and equations (3) and (5). From table 4, there are a total of 95,669,000 households.

Table 5. Annual cost of a $1 billion regulation to an individual household for different relative regulatory costs

Income range (1991 $)	Relative regulatory costs		
	Equal costs	Costs proportional to income	Proportional to income with luxury tax above $50,000
Under $5,000	$10.45	$ 0.69	$ 0.57
$5,000–$9,999	10.45	2.07	1.72
$10,000–$14,999	10.45	3.45	2.87
$15,000–$24,999	10.45	5.51	4.59
$25,000–$34,999	10.45	8.27	6.89
$35,000–$49,999	10.45	11.71	9.76
$50,000–$74,999	10.45	17.23	17.23
$75,000 plus	10.45	28.76	36.46

When each pays equally, the cost will be \$10.45, which is \$1 billion divided by the number of households. For costs proportional to income, a household with income between \$25,000 and \$34,999 would pay \$8.27.

3. Implications for expected loss of life

The expected fatalities induced by a regulatory cost of \$1 billion are presented in table 6. This table presents the results of eighteen sets of calculations for each combination of black, white, and other; male and female; and allocation of regulatory costs (equal, proportional to income, proportional with a luxury tax above \$50,000 income). Let me illustrate in table 7 the calculations for white males when regulatory costs are allocated proportional to income.

The first column in table 7 presents the income ranges. Column 2 gives the number of white households with income in the corresponding range. It is calculated by multiplying the number of white households times the proportion of white households with that income from table 4. We assume that each white household has one white male aged 25 to 64.

Column 3 is the increase in mortality risk for a white male calculated from equation (6). It begins with the assumed income for the respective income levels given in table 1 and examines the implications of the proportional cost allocated to that income given in table 5. For example, consider an income of \$35,000–\$49,999. The assumed income for such a household is \$42,500 and the proportional regulatory cost is \$11.71. From (6), the increase in risk is

$$\Delta r(\$42{,}500, \$11.71) = r(\$42{,}488) - r(\$42{,}500). \tag{8}$$

Using r in equation (1), with income in thousands of dollars and the parameters for white males in table 3, equation (8) becomes

$$\Delta r(\$42{,}500, \$11.71) = 7.21 \times 10^{-7}, \tag{9}$$

the entry in column 3 of table 7. Column 4 is the product of column 2 times column 3, which is the number of people in the income group times the increased risk per person. For the incomes in the range of \$35,000 to \$49,999, the expected number of annual fatalities is 10.54. The total number of expected fatalities for white males across all income groups for a proportional allocation of the regulatory cost is 53.14.

It is worth mentioning that some of the white households will not have a white male between the ages of 25 and 64. For these households, the share of the \$1 billion regulatory cost will fall on adult males not aged 25 to 64 and be proportionally greater on children and female household members. This would increase risks to females aged 25 to 64, which are calculated assuming both a male and female household member, and increase

Table 6. Expected fatalities induced by a $1 billion regulatory cost

(a) Assuming costs are allocated equally among all households

Income range (1991 $)	White		Black		Other	
	Male	Female	Male	Female	Male	Female
Under $5,000	11.78	7.32	8.42	6.00	0.68	0.42
$5,000–$9,999	23.12	12.63	9.28	6.11	0.66	0.36
$10,000–$14,999	18.46	8.86	4.51	2.75	0.68	0.33
$15,000–$24,999	25.03	9.90	4.72	2.55	0.89	0.35
$25,000–$34,999	14.20	4.34	2.08	0.96	0.49	0.15
$35,000–$49,999	9.40	2.08	1.03	0.39	0.29	0.06
$50,000–$74,999	3.48	0.46	0.22	0.06	0.13	0.02
$75,000 plus	0.36	0.02	0.01	0.00	0.02	0.00
All incomes[a]	105.84	45.61	30.26	18.84	3.83	1.69

(b) Assuming costs are allocated proportional to household income

Income range (1991 $)	White		Black		Other	
	Male	Female	Male	Female	Male	Female
Under $5,000	0.78	0.48	0.55	0.40	0.04	0.03
$5,000–$9,999	4.57	2.50	1.83	1.21	0.13	0.07
$10,000–$14,999	6.08	2.92	1.49	0.91	0.22	0.11
$15,000–$24,999	13.20	5.22	2.49	1.35	0.47	0.18
$25,000–$34,999	11.24	3.43	1.65	0.76	0.39	0.12
$35,000–$49,999	10.54	2.33	1.15	0.44	0.32	0.07
$50,000–$74,999	5.73	0.76	0.36	0.10	0.21	0.03
$75,000 plus	1.00	0.04	0.03	0.00	0.04	0.00
All incomes[a]	53.14	17.69	9.55	5.16	1.83	0.61

(c) Assuming costs are allocated proportional to household income up to $50,000 with a luxury tax at twice the rate above $50,000 income

Income range (1991 $)	White		Black		Other	
	Male	Female	Male	Female	Male	Female
Under $5,000	0.65	0.4	0.46	0.33	0.04	0.02
$5,000–$9,999	3.81	2.08	1.53	1.01	0.11	0.06
$10,000–$14,999	5.07	2.43	1.24	0.75	0.19	0.09
$15,000–$24,999	11.00	4.35	2.07	1.12	0.39	0.15
$25,000–$34,999	9.36	2.86	1.37	0.63	0.32	0.10
$35,000–$49,999	8.78	1.94	0.96	0.36	0.27	0.06
$50,000–$74,999	5.73	0.76	0.36	0.10	0.21	0.03
$75,000 plus	1.27	0.06	0.03	0.01	0.05	0.00
All incomes[a]	45.68	14.89	8.03	4.32	1.58	0.51

[a]Totals for columns may include small roundoff inconsistencies.

Table 7. Illustrative calculations of expected fatalities for white males assuming regulatory costs are allocated proportional to income

(1) Income range (1991 \$)	(2) Number of people with income in range (Np_i)	(3) Increase in risk mortality for each individual [Δr (x_i, $C(x_i)$)]	(4) Expected fatalities (2) × (3)
Under \$5,000	3,022,000	2.57 E-07	0.78
\$5,000–\$9,999	7,432,000	6.15 E-07	4.57
\$10,000–\$14,999	7,432,000	8.19 E-07	6.08
\$15,000–\$24,999	14,130,000	9.34 E-07	13.20
\$25,000–\$34,999	12,578,000	8.93 E-07	11.24
\$35,000–\$49,999	14,620,000	7.21 E-07	10.54
\$50,000–\$74,999	13,313,000	4.31 E-07	5.73
\$75,000 plus	9,148,000	1.09 E-07	1.00
Total	81,675,000		53.14

risks to others (i.e., not aged 25 to 64), which are not calculated. The resulting expected fatalities induced by a \$1 billion regulatory cost would not substantially vary from those indicated in table 7.

To calculate the expected fatalities to persons in other households, I used the distribution for other household income listed in table 4 and the respective mortality risk parameters for white males and white females, as there were no separate data for those mortality risks. Since other households only account for 3% of all households, any change in the mortality risk parameters would not change the overall implications for cost induced fatalities.

3.1 Cost to induce a fatality

The expected fatalities in table 6 induced by a \$1 billion regulatory cost are tabulated in table 8 for the three different allocations of regulatory costs. Dividing the \$1 billion by the expected number of fatalities gives the cost inducing one fatality. The range is from \$4.85 million for an equal cost allocation to \$13.33 million for the proportional to income allocation with a luxury tax above \$50,000 household income.[2]

3.2 Induced fatalities of different income groups

The expected fatalities to each income group induced by a \$1 billion regulatory cost are given in table 9, which was tabulated from table 6. For each cost allocation, four of the eight income groups have expected fatalities in greater proportion than their percentage of households. For an equal cost allocation, 80.5% of the expected fatalities occurs to individuals in households with incomes less than \$25,000 annually. These account for 41.7% of the households.

Table 8. Induced fatalities due to economic costs for different cost allocations

Expected fatalities due to $1 billion 1991 cost			
	Relative cost allocation		
Group	Equal	Proportional to income	Proportional to income with luxury tax above $50,000
White males	105.84	53.14	45.68
White females	45.61	17.69	14.89
Black males	30.26	9.55	8.03
Black females	18.84	5.16	4.32
Other males	3.83	1.83	1.58
Other females	1.69	0.61	0.51
Combined	206.07	87.98	75.01
Cost-inducing fatality in millions of 1991 dollars			
Combined	$ 4.85	$11.37	$13.33

With the proportional to income cost allocations, with and without a luxury tax, individuals in households with income between $5,000 and $35,000 suffer a disproportionate share of expected fatalities. However, the imbalance is not as great as it is with equal relative cost. For proportional to income relative costs, 71% of the expected fatalities occur in 52.1% of the households with income between $5,000 and $35,000. When the luxury tax is added, the proportion of expected fatalities to this group drops slightly to 69.4%.

Table 9. Induced fatalities for different income groups due to economic costs (expected fatalities due to $1 billion in 1991 dollars)

		Relative cost allocation					
		Equal		Proportional to Income		Proportional to income with a luxury tax above $50,000	
Income range	Percentage of households	Expected fatalities	Percentage of expected fatalities	Expected fatalities	Percentage of expected fatalities	Expected fatalities	Percentage of expected fatalities
Under $5,000	4.8	34.62	16.8	2.28	2.6	1.90	2.5
$5,000–$9,999	10.1	52.16	25.3	10.31	11.7	8.60	11.5
$10,000–$14,999	9.4	35.59	17.3	11.73	13.3	9.77	13.0
$15,000–$24,999	17.4	43.44	21.1	22.91	26.0	19.08	25.4
$25,000–$34,999	15.2	22.22	10.8	17.59	20.0	14.64	19.5
$35,000–$49,999	17.3	13.25	6.4	14.85	16.9	12.37	16.5
$50,000–$74,999	15.4	4.37	2.1	7.19	8.2	7.19	9.6
$75,000 plus	10.4	0.41	0.2	1.11	1.3	1.42	1.9
Total	100.0	206.06	100.00	87.97	100.0	74.97	99.9

3.3 Induced fatalities of different racial groups

The available information allows us to examine differential effects of cost-induced fatalities on blacks and Hispanics. Table 10 presents the results, where Hispanics may be of any of the three races in the table.

Previous studies have shown that cost-induced fatalities are a greater burden to blacks than other groups (Baquet et al., 1991; Sorlie et al., 1992; Pappas et al., 1993). This analysis shows that cost-induced fatalities to blacks occur at over twice the rate to whites. If regulatory costs are equally borne by all households, \$2.36 million of reduced income induces a black fatality. If the costs are borne proportionately to income, then \$4.92 million induces a black fatality. For an equal cost allocation, blacks account for 23.8% of the expected fatalities, even though they account for just 11.6% of the households. For the proportional allocation of costs, without and with a luxury tax, the percentages of expected fatalities to blacks are 16.7% and 16.5% respectively.

Both the lower income levels and the different mortality risk curves for whites and blacks contribute to the higher mortality rate. For the 11.6% of males that are black, there are 30.26 expected fatalities. For an equivalent population of white males, there would be 14.38 expected male fatalities given the equal relative cost allocation. If black income remained the same, but the mortality risk curve changed to that for whites, there would be 21.43 expected black fatalities. If the black mortality risk curve remained the same, but black income changed to equal that for whites, there would be 19.28 fatalities. The income effect is the larger one for males. Just the reverse is true for black females. With an equal cost allocation, there are 18.84 expected fatalities, due to the \$1 billion cost. If the mortality risk curve shifted to that for white females, the expected fatalities would drop to 10.53. If the income levels change to that for whites but the mortality risk curve remained the same, the expected number of fatalities would become 14.36.

Table 10. Induced fatalities for different racial/ethnic groups due to economic costs (expected fatalities due to \$1 billion in 1991 dollars)

		Relative cost allocation					
		Equal		Proportional to income		Proportional to income with a luxury tax above \$50,000	
Racial/ethnic group	Proportion of households	Expected fatalities	Proportion of expected fatalities	Expected fatalities	Proportion of expected fatalities	Expected fatalities	Proportion of expected fatalities
Whites	85.4	151.45	73.5	70.83	80.5	60.57	80.7
Blacks	11.6	49.10	23.8	14.71	16.7	12.35	16.5
Other	3.0	5.52	2.7	2.44	2.8	2.09	2.8
Total	100.0	206.06		87.98		75.01	
Hispanic	6.7	15.69	7.6	6.11	6.9	5.17	6.9

For Hispanic households, the white mortality rate was used as data were not separately available for Hispanics on overall mortality risks. Using the Hispanic income distribution from table 4, there would be 15.69 expected fatalities given an equal cost allocation to pay \$1 billion. This implies that the 6.7% Hispanic households account for 7.6% of the expected fatalities. For proportionate costs, without and with a luxury tax above \$50,000, the expected fatalities to Hispanics are 6.11 and 5.17 respectively. These each account for 6.9% of the expected fatalities for the two cases.

3.4 Implications of concentrating costs on an industry

The costs of many regulations may fall disproportionately on a single industry (e.g., the regulated industry). One would expect that the implications of costs would spread beyond any single industry, but to get a feeling for the implications of cost-induced fatalities in such cases, we assumed all costs would be borne within that industry. Specifically, we defined the industry to include one out of every hundred households and considered the implications of \$1 billion in regulatory costs spread equally over those households. Now, rather than each household paying \$10.45 as in table 5, each household in the industry now pays \$1,045.

Because the mortality risk curves in figure 1 indicate that each additional \$10 cost increases risk more than the last \$10, there will be more expected fatalities induced by regulatory costs when they are concentrated. However, the effect was not too large. For the \$1 billion previously allocated as \$1,045 to each household, the expected fatalities were 212. This is just an increase of 2.9% above the case where costs were allocated over 100 times more households. However, if some of the individuals in the industry lost their jobs, the \$1 billion cost would be very unevenly allocated across the industry and the resulting increase in cost-induced fatalities could be much more significant.

4. Cost-induced fatalities over time

It is interesting to examine how cost-induced fatalities have varied over time. The results, shown in table 11 in 1991 dollars, show that the amount of regulatory costs that induces a fatality appears to have remained very stable since 1960 (see also Duleep, 1989). The data for the original two calculations used 1960 and 1980 cross-sectional census tract information. The more recent data are from the large longitudinal study from the period 1978–1985. Because sufficient data were available only for whites in the 1960 and 1980 studies, the information from the recent longitudinal study is broken out for whites, in addition to all races, for better comparison. The costs that induce black fatalities are also shown in table 11.

The results in table 11 are perhaps surprising because both income levels and the age-adjusted mortality rates have changed over time.[3] In the 1960 data, the age-adjusted annual fatality rates for white males and white females were 0.9% and 0.55% respectively. In the recent longitudinal study, the corresponding rates were 0.65% and 0.35%.

Table 11. Cost that induces a fatality over time

	Year of mortality risk data					
	1960[b]	1980[c]	1979–1985[d]			
Relative costs[a]	Whites only	Whites only	All races	Whites only	Blacks only	Whites only fit income distribution[e]
Equal	$ 5.20	$ 5.64	$ 4.85	$ 5.63	$2.36	$ 5.85
Proportional to income	$12.00	$10.74	$11.37	$12.62	$4.92	$12.32

[a]All costs in millions of 1991 dollars.
[b]Cross-sectional census tract data from Chicago area (Kitagawa and Hauser, 1973).
[c]Cross-sectional census tract data from Los Angeles area (Frerichs et al., 1984).
[d]Longitudinal individual data from all areas in the United States (Rogot et al., 1992).
[e]The 1991 income data directly used in the other calculations for the 1979–1985 results were first fit to parameters for a gamma probability distribution describing income and this was used in calculating the results. This was the method used with the 1960 and 1980 results in the table.

The calculations for the 1960 and 1980 data in table 11 used the gamma probability distribution fit to the census income data (Keeney, 1990). The calculations for the 1979–1985 longitudinal study used 1991 income categorized into the eight discrete ranges listed in table 1. To see if this could have altered our results, we used the white income data in table 4 to fit a gamma probability distribution to income as in the previous study. Using this income distribution and the white mortality risk curves, the expected fatalities combined for white males and females induced by a $1 billion cost were 170.85 and 81.15 respectively for costs allocated equally and proportional to income. This results in a fatality being induced by $5.85 million and $12.32 million for the corresponding cost allocations. This is not significantly different from the results calculated directly from the income data.

5. Comments on the model

The calculations done using 1960 and 1980 data relating mortality to income relied on average income and mortality rates for census tracts (see Kitagawa and Hauser, 1973; Frerichs et al., 1984). They were both based on cross-sectional studies. Duleep (1986a) and Sinsheimer (1991) raised the issue of using average group data to make inferences about individuals. The Rogot et al. (1992) data do not have this problem, as they are data collected for individuals in a longitudinal study.

If an individual's usable income is lowered by $10, that person likely does not change anything that might manifest itself as an increase in the person's annual risk. For an individual, the risk mortality curve may look something like that in figure 4. Averaging over thousands of such curves, we get the exponential mortality risk curve in figure 1. This curve does not necessarily apply to any individual. It represents statistical risks and is used to calculate statistical fatalities.

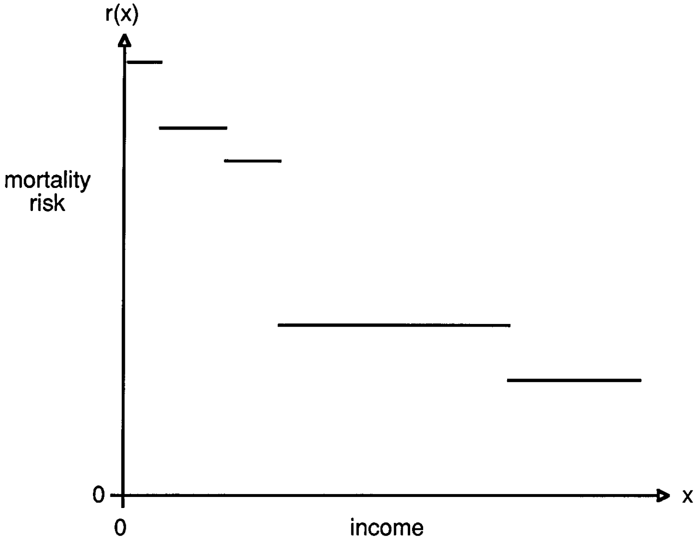

Figure 4. Possible individual annual mortality risk as a function of income.

The statistical fatalities calculated in this article assumed that people of equal income paid equivalent dollar amounts to pay for regulatory costs. However, not everyone with the same income will pay the same amount. For example, for the equal cost allocation of $1 billion, each household needed to pay $10.45. What if some households paid $14.45 and others $6.45? The answer is that the results insignificantly change. Even over ranges of $1,000, the additional increase in risk to those paying more is almost entirely offset by the decrease in risk of those paying less. This is demonstrated with calculations where all of the cost burden falls on individuals in one industry. When the $1 billion is paid by 1% of the households, that 1 percent each pays $1,045 and the others pay zero. Relative to the case where every household pays $10.45, the total expected fatalities increases only 2.9%. Variations of costs among people of equal income would certainly lead to a smaller effect.

6. Conclusions

Having usable income reduced by the costs of regulations leads to higher mortality risks and resulting fatalities. The excess mortality is not insignificant. A $5 million to $14 million cost broadly passed on to the public induces one fatality depending on how that cost is spread across individuals with different income.

The amount of regulatory cost that induces a statistical fatality has remained remarkably stable over time. Using three sets of data relating mortality to income in 1960, 1980, and 1979–1985, the cost to induce a fatality to the white population (the earlier studies only had sufficient data for white fatalities) has been $5.20, $5.64, and $5.63 million respectively when costs are equally allocated to all white households.

Our country has numerous regulations that spend tens of millions, hundreds of millions, and even billions of dollars to avoid one statistical fatality (Morrall, 1986; Tengs et al., 1995). It would be responsible to review these regulations and examine their appropriateness in light of their cost-induced fatalities. It does not seem reasonable or desirable to reduce risks enough to avoid one statistical fatality if the costs to do this will induce more than one additional statistical fatality (Keeney, 1994). A Court of Appeals rejected a proposed expensive regulation that had such a property (Williams, 1991). When there are other benefits in addition to avoided fatalities of proposed regulations, these other benefits also need to be credited in an overall evaluation of the regulation. However, this would not change the appropriate value trade-off between economic costs and statistical fatalities for calculating the equivalent value of the avoided statistical fatalities.

The results of this paper provide some guidance for making that value trade-off. It is necessary as there are many ways that our society can spend its funds to make our lives safer (Lave, 1981; Zeckhauser and Viscusi, 1990). Spending these funds, which is really spending the money of individuals in society, also makes our lives riskier. For value trade-offs greater than $14 million for each statistical life, we could be causing more deaths than we are saving. Making wise decisions about investing public funds to save lives is clearly important. Recognizing cost-induced fatalities and making the necessary value trade-off between costs and statistical lives explicitly should help in making wise decisions.

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Notes

1. This work assumes that the relationship between lower income and higher mortality risks is a causal relationship. However, it has not been proven that the relationship is entirely causal. There are other possible explanations for part of this relationship.

   One explanation is reverse causality, namely that higher mortality risks lead to lower income. A related explanation is that a common variable, such as health or education, may affect both income and mortality risk. Chapman and Hariharan (1994) analyze these possibilities and conclude that there is a significant causal effect of income on mortality risk. Also, there is a reverse causality as better health leads to higher incomes. To the degree that poorer health leads to less income, it may also then be that this lower income leads to even worse health. With both causality and reverse causality, there is a negative spiral with lower income leading to higher mortality at various stages of that spiral.

   As a result of either reverse causality or possible common variables, the regulatory expenditures calculated to induce a statistical fatality may need to be scaled up somewhat. Indeed, Chapman and Hariharan's analysis that addressed such concerns concluded that $12.2 million of 1990 dollars induced one fatality.
2. Viscusi (1994) examines in detail one of the pathways that reduced income leads to increased mortality risk. He analyzes how reduced income results in reduced expenditures on health, which in turn increases

mortality risks. Viscusi determines that the marginal propensity to spend on health is around 0.1 and concludes from this that \$30 million to \$70 million of cost induces a statistical fatality via this pathway. If this marginal propensity to spend on all other categories (i.e., nutrition, exercise, safety, education, and fun) is as effective at reducing mortality risks, then the \$30 million to \$70 million figures need to be divided by ten for an overall cost that induces a statistical fatality. Such estimates would be very consistent with those calculated in this paper. In recent research along this line, Lutter, Morrall, and Viscusi (1996) consider income effects on excessive drinking, exercise, smoking, and being overweight and conclude that via these pathways, a \$15 million decrease in income is associated with one additional statistical fatality.

3. A referee pointed out that as more information becomes available, it will be intriguing to investigate in more detail the cost in real dollars that has induced a statistical fatality in different time periods. It would be useful to understand why the real cost has remained so stable over time.

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