Journal of Risk and Uncertainty, 8:19-41 (1994)

The Fatality and Injury Costs of Expenditures

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Abstract

All production activities generate health risks to workers. This article employs input-output analysis in conjunction with job-risk data by industry to construct measures of the direct and indirect risks imposed by expenditures. Both fatalities and nonfatal injuries (which include illnesses) are considered. The occupational-risk component of expenditures is generally in the range of 3-4% of costs, with nonfatal injuries contributing the larger share. Expenditure levels that generate a fatality or a lost-workday injury are provided by industry, as are a variety of other measures that consider both created and avoided risks pertinent to risk-risk analyses and cost-effectiveness analyses, respectively.

Key words: input-output analysis, fatality costs, risk-risk analysis

Measures to reduce risks create new risks of their own. This phenomenon is well-known in relation to choice of technologies—for example, prohibiting a food preservative increases the risk of food poisoning; stopping a nuclear plant increases the health risks from plants powered by fossil fuels—though often such induced risks are not adequately taken into account. Created risks tend to be ignored completely when new expenditures are principally designed for risk reduction, as with the production and installation of pollution-control equipment or the cleanup of Superfund sites. Such cleanup at a single site, for example,[1] may involve thousands of man-hours of work with heavy earth-moving equipment, as well as worker exposure to the risks of toxic chemicals and automobile commuting. Yet, the overall cleanup may achieve minimal reductions in risk.[1] In considering both the design of regulations and ways to meet them, it would be desirable to employ a benefit-cost analysis, taking into account all categories of consequences of the expenditures—e.g., health promotion and health curtailment, dollars not available for

*Viscusi's research was supported by EPA Cooperative Agreement number CA-814-388-02 with Duke University. Zeckhauser's research was supported by grant number SES91-11056 from the Decision, Risk and Management Science division of the National Science Foundation. Wassily Leontief and Mark Dreyfus provided excellent input. Please direct all correspondence to Professor Viscusi.

other activities, and environmental gains and losses. Many "health-promoting" regulations, however, proscribe such analysis, in large part to hide any implicit tradeoffs between lives and dollars. (Those who make, implement, or otherwise support a policy may not recognize created-risk costs, or they may choose to ignore them because of personal values, proclivities, or interests.)

Risk-risk analysis provides a useful second-best measure, at least ensuring that health costs are not ignored. The possibility that regulatory costs generate risks has long been discussed, but never implemented. This article represents the first step along the path toward estimating the health costs of various categories of expenditures intended to reduce risk.[2]

Direct expenditure risks fall into two categories: occupational risks to workers and external environmental risks to society at large. We address the first category, documenting the level of the occupational fatality and the injury and illness costs associated with expenditures for output of various industries. Unfortunately, data are not readily available for external costs, such as environmental pollution by industry, so our estimates do not include those risk costs of industrial activity.

Health consequences must frequently be tallied separately in choosing a preferred public expenditure or regulatory program. If the health losses are due to some external effect, such as environmental pollution, then private decision makers will not automatically take them into account. Appropriate government interventions for coping must be informed by an assessment of costs and benefits.

In contrast, when health risks are conveyed privately, most economists would argue that the private market will generate efficient outcomes. If, as is the case in this article, occupational safety is the concern, workers' pay will reflect compensating differentials due to risk. This will lead management to trade off appropriately between risk reduction and additional expenditures. The resulting higher wages will be reflected in the costs associated with the industry's output. The occupational risk costs will be internalized and captured in dollar cost estimates.

Society, in many domains, does not appear to respect this principle about privately-conveyed risks, and imposes levels of safety above those that would be achieved by the market. Such actions imply that the price of the product does not reflect the blood of the workers that went into producing it. We identify three reasons why society may wish to override private market decisions on risk: 1) misperception and homogenization of risk, 2) moral hazard, and 3) valuational externalities.

Assessing risk levels is a challenging task, even to experts. Not surprisingly, workers may misestimate some risks, failing to distinguish adequately among them. Thus, they may assign excessively low values to extremely high risks, and excessively high values to extremely low risks. Given this pattern of errors, products whose production risks are high (low) will be underpriced (overpriced) as a guide to efficient resource allocation.

Even if workers perceive risks perfectly, significant portions of the costs of those risks are borne by others. This implies that workers will therefore demand insufficient differentials for bearing risks. Most direct health-care costs are shared by an insurance pool, which may include people inside or outside a firm, or, as with Medicaid and Medicare, by society at large. Similarly, disability payments or welfare payments flowing to the victims of accidents or their dependents come from general funds. Rarely are firms charged appropriately for imposing such risk costs.

Even if workers and firms appropriately took account of all direct costs to society, they would ignore valuation externalities. The rest of society cares more about the coal miner's health than it does about his claim over economic resources. One consequence is that we frequently regulate risks below the levels that well-informed workers would choose for themselves.

If any of these three factors—misperception, moral hazard, or valuation externalities—is significant, privately-conveyed health risks will be undercounted in market processes. This implies that they should be tabulated separately in any cost-benefit analysis, with appropriate shadow prices attached.

The focus of this article is on government programs that reduce risks. Frequently, such programs are assessed using a cost-effectiveness analysis, where the effectiveness measure is the reduction in risk. Normally, the cost side includes health risks that are incurred due to expenditures. Most such risks will not be directly observed by those who design the program, for they may arise at an early point in roundabout production processes—for example, from mining the coal that produced the power that made the pollution-control equipment that is being put into place under the program.

We make two arguments about such health risks. First, following a central principle of public expenditure analysis, such risks should be tallied. One should know all significant consequences of expenditures. Second, they should be assigned a shadow price that reflects the sum of misperception, moral hazard, and valuation-externality concerns.

Consider a program that merely involves saving lives at a resource cost, say 100 lives from an expenditure of $2 billion. Suppose the expenditure itself is determined, by methods outlined below, to cost 10 lives, an average expenditure of $20 million per life lost. Then this program has a net life-saving effect of 90 lives, or a cost of $22.2 million per life.[3]

In many policy contexts, legislative constraints prohibit or have been accused of prohibiting trading off total costs and benefits. The U.S. Supreme Court, for example, has interpreted the provisions of the Occupational Safety and Health Act as being inconsistent with an explicit benefit-cost test. In such instances, at a very minimum, we should require a risk-risk test to demonstrate that the net effect of the policy is a reduction in risk. Such an analysis would not require converting risks to monetary terms; a discounted lives-saved or quality-adjusted life-years (QALY) metric would be sufficient to assess the overall efficacy of the policy.[4]

Risk-risk analysis gives us a critical number, namely, the net reduction in risk. In some circumstances, this net reduction will be negative. Then the decision is easy. In other cases, it will be small, and other considerations will come into play, perhaps for political reasons. If the risk-risk analysis showed the benefits to be minimal, then the political process might ultimately respond so as to change legislative requirements and prohibitions. At the other extreme, if created risks prove small relative to lives saved, they would effectively drop out of the analysis.

Economists have long recognized that occupational risk is a potentially important component of risk-risk analysis, and have offered some thoughts as to the appropriate methodology for addressing these concerns. To date, there has been no attempt to estimate occupational risk effects, in part because constructing measures of expenditure-induced risks is not straightforward.

Some relevant numbers are readily available, notably the numbers of injuries and fatalities and levels of industrial output by industry. For these statistics, the category "injuries" includes identifiable job-related illnesses. The metric is cases sufficient to cause at least one lost workday. It is a simple matter to divide a risk amount, whether of injuries or fatalities, by the output level of an industry. A naive risk measure of this nature is usually offered to indicate the danger associated with an industry. But such a measure is not what we are after, because it looks at total output rather than final output (what is ultimately consumed) from the industry, and because it ignores the risk from inputs.

To capture the risk effects of regulatory expenditures we must add the risk level associated with directly producing the final output required for compliance—for example, manufacturing a prescribed scrubber and installing it—to the risk amounts engendered by producing the inputs to that process, such as the steel, the electronics, etc. Thus, the naive risk measure—industry fatalities divided by industry output—must be adjusted in two ways. First, the injury cases that arise because the industry serves as an input for the final production of other goods must be subtracted out. Second, the risks associated with other industries as direct and indirect inputs to this good's final production must be included.

We employ input-output analysis to identify and tabulate the risks associated with final production and intermediate outputs.[5] We then generate risk levels per unit of final output by industry. For example, we can determine the health risks per dollar output of construction or industrial machinery. From such numbers we could compute the risk created by an expenditure to reduce risk. For example, how much risk is associated with efforts such as the construction of a water-pollution-control plant?

Section 1 outlines the general input-output methodology. We assess the nonfatal risks associated with industry output in section 2, and assess the mortality risks of industry output in section 3. In section 4 we combine these two concerns to yield a total risk measure associated with industry output. A dollar weighting is used to assess the value of these risks as a percent of total output for different industries. Section 5 provides general conclusions pertaining to the use of risk estimates in policy contexts.

1. The input-output methodology for risks

When considering the risks created by an expenditure, we must distinguish between the risks produced within the industry that provides the goods or services, and the risks associated with inputs to that industry. For example, to assess the health risks of the electric power industry, we must account for the substantial mortality risks associated with coal as a primary input. Failure to recognize the risks associated with inputs may lead to understating risks in what may seem to be relatively safe industries, and to overstating risks associated with industries, such as coal, which, in large part, produce inputs to other industries. Similarly, chemical products are often not a final output but serve as intermediate inputs to other industries.

This analysis classifies risks into three categories: domestic (D), exported (E), and imported (I). Domestically-generated risks for industry Q are the injuries occurring within the industry that are due to final output of that industry. Exported risks for industry Q are its injuries that are due (through Q's role as an input) to final production in other industries. Imported risks for industry Q are the injuries occurring within other industries that are due to the final output of Q.

The raw (R) injuries observed in Q, e.g., what would commonly be reported as the injuries in the steel industry, are thus its domestic plus exported injuries. If we wish to know the dangers associated with the final production of steel, the critical concept is what we call allocated (A) injuries, namely domestic injuries plus imported injuries.

Thus, we have $R = D + E$, and $A = D + I$. We will sometimes be relating allocated injuries to raw injuries: $A = R - E + I$. Notice that D, E, and I each have direct and indirect components. The input-output approach[6] relates activities in different areas of the economy, assuming fixed proportions of inputs are required to produce any output.[7] Fortunately, detailed input-output relationships are regularly estimated by the U.S. Department of Commerce. Available risk data are less refined. Starting with risk data that relate to total industry output, input-output analysis enables us to make the adjustments required to compute expenditure-induced risk.

We employ the following notation to summarize the values of industry output, the input requirements to produce each unit of output, and the risk values:

$y = n \times 1$ vector of final output, where y_i is output from industry i;
$X = n \times n$ matrix of total requirements, where X_{ij} is input of good i needed to product one dollar of output good j;
$z = n \times 1$ vector representing direct plus indirect output, where z_i is output for industry i;
$c = n \times 1$ vector of worker risks (injuries or fatalities) where c_i is number of cases observed by industry i;
$r = n \times 1$ vector of worker risk rates for total direct and indirect output of industry, where r_i is number of risk cases per unit of total output in industry i.
$a = n \times 1$ vector of allocated risk cases in the industry, where a_i is the number of risk cases in industry i.

The key input-output component is the matrix X (total requirements). The components of X indicate the input needed from each good i to produce each dollar of output of good j. These data are compiled by the U.S. Department of Commerce. This study utilized the input-output data for 1987, which are the most recent available.[8] To find the total inputs required to produce final output vector y, we multiply y by the total requirements matrix, or

$$Xy = z. \tag{1}$$

Thus, z_i is the combined output generated by industry i as a final product, and for all intermediate uses, that is, goods from industry i used to produce output of other industries.

A typical regulatory analysis would specify the amount of output required from various industries, such as the quantity of industrial machinery and the level of construction activity. If we are to produce a risk-risk analysis, or for that matter, a benefit-cost or cost-effectiveness analysis that attends to created risk, then the bottom-line question becomes: what level of risks do these final demand amounts create?

To obtain a measure of the risk per unit of output in an industry, divide the total number of cases of worker injuries or fatalities by the output from the industry, where the output measure has been transformed by equation (1) to reflect the total direct and indirect uses of the output. Thus, the appropriate baseline risk measure r_i for industry i would be a risk that recognizes the total value of output (as opposed to simply the final demand), or

$$r_i = c_i/z_i. \tag{2}$$

To obtain the total risk measure associated with each industry, we multiply the industry risk per unit of total output vector r by the input-output matrix X to yield the vector a of the total number of risk cases, or

$$r'X = a, \tag{3}$$

where the $'$ indicates that r has been transformed to a row vector. The risk cases directly attributable to production in industry i, i.e., domestic risks, are $X_{ii}r_i$. The sum $\Sigma_{i \neq j} X_{ij}r_i$ is the number of risk cases generated by inputs to that industry, i.e., imported risk. The sum of domestic and imported risk, namely, a_i, represents the total number of risk cases arising from final output in the industry. We refer to a_i as allocated risk. After obtaining the number of allocated risk cases in this manner, calculating other risk measures of concern, such as the domestic and imported risk per dollar of final industry demand, requires but simple division.

This method accounts for feedback effects, which have the consequences of tempering the relative risk levels of different industries. The estimated risks are weighted averages of the industry-specific risk and the risk levels in industries providing inputs. Very high-risk industries that draw their inputs from lower-risk industries consequently will have a lower risk level once the input-output linkages are taken into account; and very low-risk industries utilizing inputs from higher-risk industries will have higher risk levels after the feedback effects are recognized. Given the tempering effect of accounting for inputs, it is likely that government policies based on raw data are relatively too stringent on more dangerous industries and too lenient on safe industries.

To be sure, one should regulate injuries where they occur. However, if these regulations are not as stringent as is socially desired, the outputs generated by these industries will be underpriced, failing to adequately account for risk. Increased industrial production by industries that utilize these underpriced inputs consequently generates excess risks in other sectors of the economy. Taxes on final outputs that reflect the risks associated with risky inputs could enable final product prices to reflect their true social costs.

2. The injury costs of expenditures

We begin by analyzing the job injuries and illnesses generated by expenditures, injuries and illnesses that are sufficiently severe to lead to the loss of at least one day of work. Though some occupational illnesses will be captured in our risk measure, they will be undercounted. Because of difficulties in assigning causality to illnesses and the frequently substantial gestation periods before illnesses become apparent, government record keeping for illnesses is less adequate than for acute health effects, such as injuries. The typical duration of lost workday injuries is more than a day (it is in the vicinity of four weeks), and some injuries such as those that result in permanent disability are obviously of much more substantial duration.[9]

There are several nonfatal job injury data series. We choose to focus on lost workday injuries and illnesses, because this injury category has a well-defined set of definitions determining what constitutes a lost workday injury. Total injury rate data are more susceptible to reporting differences, since firms may have different standards for what constitutes a job injury. Injury data are available on a more refined industry level (the two-digit SIC level) than are the one-digit data for fatalities.[10]

The input requirements matrix consequently is a slightly aggregated version of the U.S. Department of Commerce matrix X defined in section 1. The components of this matrix give the total dollar value of the inputs required from each of the component industries (i.e., the rows) to produce one dollar of output in each industry (i.e., the columns). The largest entries in each column are the diagonal elements. On average, industry i must produce roughly 1.1 units of output to secure one unit of its final output.

The procedure described in section 1 first converts the level of output to the domestic and imported value of the output, taking into account all of these feedback effects.[11] Thus the risk estimates generated by our procedure will equal the total number of injuries or fatalities within each industry, and, by summing across industries, will equal totals for the economy.

After undertaking the procedure discussed in section 1, one can then calculate the risk associated with each industry. Table 1 summarizes some key results. The first data column shows the raw number of injury cases per 100 full-time workers attributable to both domestic and exported production. The second data column shows the allocated cases per 100 employees based on our input-output analysis. The figures in this column represent only that portion of the injuries within that industry that are attributable to the final demand for its product. However, the allocated cases also include the risks from other industry inputs used to make the product.

The degree to which these two injury tallies can differ is shown in the final column of table 1. The ratio of allocated to raw cases will be 1.0 if inter-industry flows are inconsequential. However, as can be seen, the range is quite substantial. Industries such as printing and coal mining largely serve as inputs to other industries, so failure to correct would lead to an overstatement of the risk level in these industries if one attributed all of their risk to final output. The opposite is true in the case of industries such as petroleum and coal refining, where the substantial risks associated with their inputs—that is, mining

Table 1. Comparison of raw injury and illness cases to allocated cases by industry employment

Industry	SIC Code	Raw injury and illness cases per worker	Allocated injury and illness cases per worker	Ratio: allocated cases/ raw cases
Agriculture, forestry & fishery	1,2,7–9	0.059	0.057	0.964
Metal mining	10	0.041	0.044	1.066
Coal mining	12	0.082	0.057	0.697
Oil & gas extraction	13	0.042	0.026	0.616
Nonmetallic minerals	14	0.042	0.026	0.610
Construction	15–17	0.067	0.079	1.184
Food & kindred products	20	0.099	0.127	1.286
Tobacco	21	0.032	0.073	2.271
Textiles	22	0.040	0.038	0.954
Apparel	23	0.039	0.055	1.415
Lumber & wood products	24	0.088	0.060	0.677
Furniture & fixtures	25	0.078	0.085	1.096
Paper & allied products	26	0.055	0.058	1.052
Printing & publishing	27	0.033	0.019	0.577
Chemicals & allied products	28	0.031	0.053	1.726
Petroleum & coal products	29	0.031	0.159	5.124
Rubber & miscellaneous plastics	30	0.078	0.050	0.644
Leather & leather products	31	0.059	0.067	1.140
Stone, clay, & glass products	32	0.073	0.053	0.722
Primary metal industries	33	0.081	0.070	0.861
Fabricated metal industries	34	0.079	0.063	0.800
Industrial machinery & equipment	35	0.047	0.053	1.124
Electronic & electric equipment	36	0.038	0.056	1.486
Transportation equipment	37	0.069	0.104	1.506
Instruments & related products	38	0.027	0.028	1.055
Miscellaneous manufacturing	39	0.051	0.058	1.128
Transportation	40–42,44–47	0.073	0.047	0.650
Communications	48	0.018	0.017	0.966
Electric, gas & sanitary services	49	0.039	0.061	1.576
Wholesale & retail trade	50–57,59	0.036	0.028	0.778
Finance & insurance	60–64,67	0.008	0.014	1.745
Real estate	65	0.025	0.051	2.049
Services	70,72,76	0.036	0.028	0.790
Business services	73	0.026	0.024	0.929
Eating & drinking	58	0.032	0.029	0.899
Auto repair, services, parking	75	0.034	0.047	1.384
Amusement & recreation services	79	0.041	0.035	0.853
Health, legal, educational, & social services	80–83	0.032	0.035	1.089

and oil and gas extraction—reveal the coal and refining industries to be much more dangerous than would be the case based solely on the direct risks associated with their operation.

A more detailed breakdown of the components of risk appears in table 2. The total risks, given in the first column, are divided into cases directly attributable to own final production (domestically-generated risks), and cases indirectly generated by that industry as input requirements from other industries, which we call imported risks. For example, in the case of miscellaneous manufacturing (SIC 39) there are 21,684 injuries per year overall, of which 12,150 are domestically generated cases and 9,533 are imported from other industries as risks associated with inputs. The final column summarizes the ratio of imported risks to the domestic risks. In many cases the risks associated with the final demand for the industry's products are greater than the risks associated with output that serves as input to other industries. Transportation is an excellent example of an industry in which most risks are domestic, i.e., associated with its own final demand. Industries such as metal mining, oil and gas extraction, paper, chemicals, and electrical equipment, generate more risks as inputs to other products than in producing their own final demand. The most extreme example is petroleum and coal products, for which the risks associated with inputs to the refining process are 10 times as great as the risks associated with the petroleum and coal production process itself.

The substantial impact of risks from other sources highlights the importance of disentangling the inter-industry flows and parsing the contributions to the risk levels in different industries, as opposed to simply dividing raw risk data by raw output level and ignoring interdependencies. Among the 38 major industry groups listed, including such seemingly safe industries as real estate, the risk generated by inputs to these industries is actually much greater than the raw risks associated with operation of the industry.

The principal issue of policy interest is the relationship between expenditures made in different industries and the injuries that will result. The relevant quantities to examine in an industry are 1) the total risks that are generated from both domestic and imported sources, and 2) the dollar value of its final demand. The ratio of (1)/(2) gives risk per unit of expenditure. Our analysis reported in the final column of table 3 examines the ratio of (2)/(1), namely the total value of expenditures in an industry that generates the loss of a statistical life.

In the case of high-risk per unit output industries, such as furniture and fixtures, one will generate a statistical lost workday injury with expenditures of less than $1 million. At the other end of the range is the real estate industry, where an expenditure of $10.3 million generates a lost workday injury. For the most part, however, the magnitude of expenditures required to generate a lost workday injury falls into the range of $1–$3 million.

This amount is considerably above the implicit value that workers receive as a compensating differential for the risk of a lost workday injury. Although some estimates for these injuries and illnesses have been reported in excess of $100,000 per injury, most of the estimates in the literature for injuries severe enough to cause at least one lost day of work are in the range of $50,000.[12] In the case of lost workday injuries that include

Table 2. Lost workday cases allocated over domestically-generated and imported risks

Industry	SIC Code	Allocated cases	Domestically-generated cases	Imported cases	Ratio: imported/domestic case
Agriculture, forestry & fishery	1,2,7-9	67,376	35,282	32,094	0.910
Metal mining	10	2,567	524	2,043	3.899
Coal mining	12	8,438	4,485	3,953	0.881
Oil & gas extraction	13	10,187	4,085	6,102	1.494
Nonmetallic minerals	14	2,843	1,291	1,552	1.202
Construction	15-17	407,179	260,524	146,654	0.563
Food & kindred products	20	212,366	128,337	84,030	0.655
Tobacco	21	3,568	1,567	2,001	1.278
Textiles	22	26,376	13,508	12,867	0.953
Apparel	23	57,587	35,766	21,821	0.610
Lumber & wood products	24	44,140	29,752	14,387	0.484
Furniture & fixtures	25	43,611	33,134	10,478	0.316
Paper & allied products	26	40,465	16,868	23,597	1.399
Printing & publishing	27	29,956	15,850	14,106	0.890
Chemicals & allied products	28	58,473	16,024	42,450	2.649
Petroleum & coal products	29	25,017	2,247	22,770	10.135
Rubber & miscellaneous plastics	30	44,674	26,651	18,023	0.676
Leather & leather products	31	8,892	5,906	2,986	0.506
Stone, clay, & glass products	32	29,356	17,453	11,903	0.682
Primary metal industries	33	52,713	22,918	29,795	1.300
Fabricated metal industries	34	89,972	49,799	40,173	0.807
Industrial machinery & equipment	35	110,630	59,632	50,998	0.855
Electronic & electric equipment	36	94,460	39,671	54,789	1.381
Transportation equipment	37	205,647	117,553	88,094	0.749
Instruments & related products	38	28,617	16,551	12,066	0.729
Miscellaneous manufacturing	39	21,684	12,150	9,533	0.785
Transportation	40-42,44-47	168,631	141,098	27,532	0.195
Communications	48	22,792	10,518	12,274	1.167
Electric, gas & sanitary services	49	59,094	19,739	39,355	1.994
Wholesale & retail trade	50-57,59	541,185	459,823	81,362	0.177
Finance & insurance	60-64,67	75,654	30,270	45,384	1.499
Real estate	65	67,576	22,415	45,161	2.015
Services	70,72,76	89,650	74,188	15,461	0.208
Business services	73	126,588	64,209	62,379	0.971
Eating & drinking	58	188,937	142,370	46,567	0.327
Auto repair, services, parking	75	43,669	20,698	22,972	1.110
Amusement & recreation services	79	38,060	30,204	7,857	0.260
Health, legal, educational, & social services	80-83	426,176	374,087	52,089	0.139

Table 3. Dollars of industry output per allocated injury

Industry	SIC Code	Total industry output ($ millions)	Output per injury ($ millions)
Agriculture, forestry & fishery	1,2,7-9	184,068	2.732
Metal mining	10	6,894	2.686
Coal mining	12	26,008	3.082
Oil & gas extraction	13	77,432	7.601
Nonmetallic minerals	14	11,563	4.067
Construction	15-17	596,958	1.466
Food & kindred products	20	331,699	1.562
Tobacco	21	26,409	7.402
Textiles	22	51,852	1.966
Apparel	23	81,224	1.410
Lumber & wood products	24	68,860	1.560
Furniture & fixtures	25	36,726	0.842
Paper & allied products	26	106,652	2.636
Printing & publishing	27	83,204	2.778
Chemicals & allied products	28	221,560	3.789
Petroleum & coal products	29	140,582	5.619
Rubber & miscellaneous plastics	30	84,585	1.893
Leather & leather products	31	8,763	0.986
Stone, clay, & glass products	32	62,550	2.131
Primary metal industries	33	121,977	2.314
Fabricated metal industries	34	162,414	1.805
Industrial machinery & equipment	35	210,135	1.899
Electronic & electric equipment	36	215,209	2.278
Transportation equipment	37	318,026	1.546
Instruments & related products	38	56,717	1.982
Miscellaneous manufacturing	39	33,394	1.540
Transportation	40-42,44-47	254,105	1.507
Communications	48	134,650	5.908
Electric, gas & sanitary services	49	258,752	4.379
Wholesale & retail trade	50-57,59	841,993	1.556
Finance & insurance	60-64,67	456,634	6.036
Real estate	65	693,812	10.267
Services	70,72,76	112,620	1.256
Business services	73	566,814	4.478
Eating & drinking	58	212,751	1.126
Auto repair, services, parking	75	103,186	2.363
Amusement & recreation services	79	73,100	1.921
Health, legal, educational, & social services	80-83	486,700	1.142

injuries not severe enough to lead to the loss of a day of work, injury values are as low as $20,000. As a result, the total expenditures needed to generate the occurrence of one lost workday injury are somewhere in the vicinity of 50 times as great as the implicit value of these injuries, based on what workers receive in terms of compensation for them.

The most pertinent aspect of these results is their general order of magnitude: expenditures generate lost workday injuries much more often than fatalities. The net effects on the total value of losses for risk-risk analysis are explored below.

3. Fatality effects

Our analysis of the effect of industry expenditures on deaths parallels that for injuries. The only difference is that the analysis must be undertaken at a less detailed level of aggregation, because the most consistent series of occupational fatality data is highly aggregated—it is only available on a one-digit (SIC code) basis. This analysis utilizes the National Institute of Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatality data for the years 1980–1984.[13]

The total requirements matrix X in table 4 shows the total inputs, direct and indirect, needed to produce $1 of each industry's output. The row components are the industry inputs needed to produce $1 of output for the industry in the particular column. Since these are only the commodity requirements, the information here is independent of the risk levels.[14] As in the case of the input-output matrix for injuries, the aggregation was undertaken by weighting the input coefficients proportionally to the amount of the total commodity output in each of the industries.

Examination of the structure of table 4 highlights the nature of the input-output relationships.[15] To produce $1 of final demand of manufacturing output requires $1.65 of total manufacturing output, of which $1 represents final product and $0.65 represents manufacturing output that serves as inputs to manufacturing goods. All other entries in the fourth column of table 4 represent the dollar value of inputs to make $1 of manufacturing goods.

Table 5 summarizes the risk levels implied by the input-output calculations using the fatality rates. The first two columns summarize the raw reported fatalities for the industry and the fatality rate per worker. The typical fatality rate per full-time worker is on the order of 1/10,000 per year. The third column gives the fatality rate based on the allocated fatality risk amounts, comparing domestic and imported risks. The final column gives the ratio of the allocated fatalities to the raw fatality figures. In some industries, such as finance, insurance, and real estate, the total fatalities associated with the industry dramatically exceed the raw fatalities directly associated with production in that industry.

The primary impact of focusing on inter-industry flows through the input-output analysis is that fatality risk levels are homogenized: overall they become more similar across industries. As can be seen by comparing the second and third columns in table 5, the high-risk industries, such as agriculture and mining, have lower risk per worker when evaluated by the allocated fatality amounts, rather than raw fatality amounts. Similarly,

Table 4. Industry by commodity total requirements matrix*

		Final product industry							
		Agriculture	Mining	Construction	Manufacturing	Transportation & utilities	Wholesale & retail trade	Finance, insurance & real estate	Services
Commodity inputs	+ Agriculture, forestry & fisheries	1.4269	0.0035	0.0130	0.0823	0.0035	0.0280	0.0074	0.0092
	+ Mining	0.0452	1.0959	0.0459	0.0861	0.1101	0.0163	0.0067	0.0170
	+ Construction	0.0275	0.0271	1.0131	0.0216	0.0654	0.0167	0.0392	0.0257
	+ Manufacturing	0.3612	0.1969	0.5420	1.6464	0.1794	0.1820	0.0744	0.3428
	+ Transportation & utilities	0.0903	0.0749	0.0871	0.1187	1.0683	0.0745	0.0416	0.1113
	+ Wholesale & retail trade	0.0795	0.0451	0.1285	0.1175	0.0451	1.0559	0.0293	0.0614
	+ Finance, insurance & real estate	0.1555	0.2383	0.0569	0.0774	0.0908	0.0981	1.2266	0.1094
	+ Services	0.0890	0.0742	0.1540	0.1140	0.0720	0.1486	0.0876	1.4695

*Matrix was aggregated from U.S. Dept. of Commerce industry by commodity total requirements matrix, where input-output coefficients were derived based on total commodity output.

Table 5. Raw and allocated fatalities by industry

Industry	Raw fatalities	Raw fatalities per worker	Allocated fatalities per worker	Ratio: allocated fatalities/ raw fatalities	Allocated fatalities
Agriculture, forestry & fisheries	707	5.97E-04	3.34E-04	0.5596	396
Mining	315	4.43E-04	1.45E-04	0.3277	103
Construction	952	1.85E-04	1.69E-04	0.9095	866
Manufacturing	838	4.39E-05	7.41E-05	1.6901	1,416
Transportation & utilities	901	1.55E-04	1.03E-04	0.6683	602
Wholesale & retail trade	343	1.40E-05	1.73E-05	1.2364	424
Finance, insurance & real estate	72	6.01E-06	1.62E-05	2.6969	194
Services	545	3.06E-05	3.78E-05	1.2322	672

Table 6. Incidence of fatalities allocated by domestically-generated and imported risk

Industry	Allocated fatalities	Domestically-generated fatalities	Imported fatalities	Ratio: imported/ domestic fatalities
Agriculture, forestry & fisheries	396	355	41	0.1142
Mining	103	85	19	0.2186
Construction	866	715	151	0.2106
Manufacturing	1,416	636	780	1.2274
Transportation & utilities	602	468	135	0.2879
Wholesale & retail trade	424	233	191	0.8212
Finance, insurance & real estate	194	51	143	2.8211
Services	672	403	269	0.6680

the very low-risk industry groups, such as finance, insurance, and real estate, have a higher fatality rate once their linkages are taken into account.

The components that give rise to the allocated risk levels in table 5 are distinguished in table 6. This table divides the allocated fatalities into three components: allocated fatalities, domestically-generated fatalities associated with production in the industry, and imported fatalities generated by industries that serve as inputs to production. For two industry groups—manufacturing and finance, insurance, and real estate—imported fatalities exceed domestic fatalities.

The level of expenditure in each industry that will generate the loss of a statistical life is considerably larger than the expenditure that will generate a statistical injury. As can be seen from table 7, the amount of expenditure that will lead to the loss of one life ranges from $465 million for agriculture to $5.9 billion for finance insurance and real estate.

Of course, while the expenditure levels needed to generate a statistical death are substantial, the value to society of each life is quite large as well. Risk-risk analysis tells us whether the injuries due to expenditures outweigh the gains the expenditures produce. Occasionally—for highly ineffective expenditures—they do. In less extreme cases, we should be concerned with whether recognizing the lives lost due to expenditures might be sufficient to tip the balance, so that projects that are cost-ineffective are not undertaken.

As tables 3 and 7 show, the expenditure per case is nearly three orders of magnitude greater for lost lives than for lost workday injuries, obviously because the latter are so much more common. An interesting measure of the character of the risk in different industries is the severity of danger measure: the ratio of the number of fatalities to the number of lost workday cases by industry. Industries with high severity of danger ratios have a high relative number of fatalities compared to total lost workday injuries, and consequently have a more severe mix of injuries.

Table 8 summarizes the severity of danger indices for the standard published risk levels for each industry, which do not take into account indirect injuries deriving from inputs (table 8a), and for the risk values obtained using the input-output allocation of the risks (table 8b). The differences in these values reflect the role of the inter-industry flows of resources, which push toward greater uniformity in risk levels. The severity of danger index for the raw measures of injuries ranges from .0004 to .0101, which is a factor of 25. In the case of the measures based on the input-output allocation, the severity of danger index ranges from .0006 to .0059, a factor of 10. Allocated risk measures fall in a much narrower range than the raw risk measure. This is because the input-output approach accounts for feedback effects, in effect making the risk a weighted average of the multiple risks across industries.

Table 7. Dollars of industry output per allocated fatality

Industry	Total industry output ($ millions)	Output per fatality ($ millions)
Agriculture, forestry & fisheries	184,068	465
Mining	121,897	1,181
Construction	596,958	689
Manufacturing	2,422,538	1,710
Transportation & utilities	647,507	1,075
Wholesale & retail trade	1,054,744	2,487
Finance, insurance & real estate	1,150,446	5,925
Services	1,342,420	1,999

Table 8a. Severity of danger index by industry (raw)

Industry	Raw injuries	Raw fatalities	Fatalities per injury
Agriculture, forestry & fisheries	69,891	707	0.0101
Mining	35,724	315	0.0088
Construction	344,032	952	0.0028
Manufacturing	1,105,488	838	0.0008
Transportation & utilities	320,518	901	0.0028
Wholesale & retail trade	905,693	343	0.0004
Finance, insurance & real estate	76,329	72	0.0009
Services	717,132	545	0.0008

Table 8b. Severity of danger index by industry (allocated)

Industry	Allocated injuries	Allocated fatalities	Fatalities per injury
Agriculture, forestry & fisheries	67,376	396	0.0059
Mining	24,036	103	0.0043
Construction	407,179	866	0.0021
Manufacturing	1,228,203	1,416	0.0012
Transportation & utilities	250,517	602	0.0024
Wholesale & retail trade	730,122	424	0.0006
Finance, insurance & real estate	143,231	194	0.0014
Services	724,143	672	0.0009

4. Monetary valuations of injuries

Knowing what expenditure generates the loss of a statistical life or an injury is instructive; such figures indicate how frequently these adverse health effects would be generated by a specific regulatory expenditure. However, risk-risk analysis should ultimately put fatalities and lost workday injuries on a comparable basis to produce a single metric of health loss. Measuring each of these two health effects in dollar terms makes it possible to convert them into a single metric.

This normalization can be undertaken using existing figures on the statistical values of lives and injuries. In addition, by applying these statistical values, one can convert the health effects into total monetary equivalents. These monetary values can be used to monetize the risk effects to compare the monetized risk component of costs and the monetized risk reduction benefits. (Alternatively, these money measures can be thought of simply as weighting factors, giving us a measure of total occupational health losses in an industry.)

The form of risk analysis we prefer is highly flexible, particularly given that policies have multiple risk effects, including the expenditure-induced risks discussed here. The rationale for our approach within the context of risk-risk analysis is that if only risks are being considered, and total expenditure costs are not, then at least the risk component of these costs should be addressed. It is often useful to convert diverse risk effects into a single metric by assigning appropriate dollar values, but this procedure is only a mechanism for facilitating risk-risk comparisons, not for introducing economic concerns other than risk. We also have an independent concern with the injuries, either because the market is imperfect—lack of worker perceptions or moral hazard, for example—or because we have some regulatory requirement to reduce risk even if the reduction is inefficient (measuring benefits in terms of compensating wage differentials).

To convert risk effects into monetary terms, we use valuations based on labor-market estimates of the implicit value of job injuries and fatalities.[16] In the case of injury valuations, the midpoint estimate for an injury severe enough to lead to a lost workday (which of course includes much more severe injuries as well) is $50,000. This estimate is low; it reflects the risk-dollar tradeoff that workers make when they know that workers' compensation will cover much of the income loss and medical costs associated with injuries. Thus, empirical estimates suggest that the social value of injuries may be 50% larger than this amount, based on estimates of how the implicit valuations of injuries would be changed if workers' compensation were eliminated.[17]

The estimates in table 9 indicate the value of the injuries using a value per injury of $50,000. Estimates for an injury value of $20,000, for example, can be obtained by multiplying these valuation amounts and ratios by 0.4,[18] and similarly for other valuation amounts. The cost of injuries is often quite substantial, particularly in the high-risk industries. For example, in the case of construction, the total value of the nonfatal lost workday injuries is over $20 billion annually. As a percentage of total output, the highest nonfatal injury amount is for leather products, for which the injury cost is 5%. Other industries, such as real estate, are comparatively safe, and the value of the injuries is much smaller in relation to industry output.

We calculated the dollar value of fatalities based on labor-market studies of worker wage-risk tradeoffs, which suggest that the implicit value-of-life range for workers is from $3–$7 million ($5 million being the midpoint of this range). This sizable range exists in part because of heterogeneity among workers in the different studies. For example, studies focusing on less affluent workers and workers who have selected very high-risk jobs tend to find lower implicit values of life. Table 10 uses the midpoint of the estimated range for the implicit value of life. Estimates below, using a value of life of $3 million, the lower end of the range, are simply .6 of the values in table 10. Across industries, the ratio of valuation/output varies by a factor of 13. Although the total value of fatalities is often substantial, they account for a much smaller relative share of industry output than do lost workday injuries. Whereas the estimates in table 9 implied that injuries in the construction industry are over 3% of the total value of industry output, the value of fatalities in the same industry is under 1% of the value of industry output.

This pattern of results implies a more general lesson for risk-risk analysis and for society's treatment of health risks. The focus on the media, government action, and indeed of the economics profession is much more on fatal than on nonfatal injuries. We all learn of the factory fire or scaffolding collapse which leads to multiple deaths, but most of us never hear of the daily toll of fractures and lacerations in industries across the

Table 9. Injury costs of output (injuries valued at $50,000 each)

Industry	SIC Code	Allocated injuries	Valuation of losses ($ millions)	Ratio: valuation to output
Agriculture, forestry & fishery	1,2,7–9	67,376	3,369	0.0183
Metal mining	10	2,567	128	0.0186
Coal mining	12	8,438	422	0.0162
Oil & gas extraction	13	10,187	509	0.0066
Nonmetallic minerals	14	2,843	142	0.0123
Construction	15–17	407,179	20,359	0.0341
Food & kindred products	20	212,366	10,618	0.0320
Tobacco	21	3,568	178	0.0068
Textiles	22	26,376	1,319	0.0254
Apparel	23	57,587	2,879	0.0354
Lumber & wood products	24	44,140	2,207	0.0321
Furniture & fixtures	25	43,611	2,181	0.0594
Paper & allied products	26	40,465	2,023	0.0190
Printing & publishing	27	29,956	1,498	0.0180
Chemicals & allied products	28	58,473	2,924	0.0132
Petroleum & coal products	29	25,017	1,251	0.0089
Rubber & miscellaneous plastics	30	44,674	2,234	0.0264
Leather & leather products	31	8,892	445	0.0507
Stone, clay, & glass products	32	29,356	1,468	0.0235
Primary metal industries	33	52,173	2,636	0.0216
Fabricated metal industries	34	89,972	4,499	0.0277
Industrial machinery & equipment	35	110,630	5,531	0.0263
Electronic & electric equipment	36	94,460	4,723	0.0219
Transportation equipment	37	205,647	10,282	0.0323
Instruments & related products	38	28,617	1,431	0.0252
Miscellaneous manufacturing	39	21,684	1,084	0.0325
Transportation	40–42,44–47	168,631	8,432	0.0332
Communications	48	22,792	1,140	0.0085
Electric, gas & sanitary services	49	59,094	2,955	0.0114
Wholesale & retail trade	50–57,59	541,185	27,059	0.0321
Finance & insurance	60–64,67	75,654	3,783	0.0083
Real estate	65	67,576	3,379	0.0049
Services	70,72,76	89,650	4,482	0.0398
Business services	73	126,588	6,329	0.0112
Eating & drinking	58	188,937	9,447	0.0444
Auto repair, services, parking	75	43,669	2,183	0.0212
Amusement & recreation services	79	38,060	1,903	0.0260
Health, legal, educational, & social services	80–83	426,176	21,309	0.0438

Table 10. Fatality costs of output valued at $5 million per fatality

Industry	Allocated fatalities	Valuation of losses ($ millions)	Ratio: valuation to output
Agriculture, forestry & fisheries	396	1,978	0.0107
Mining	103	516	0.0042
Construction	866	4,329	0.0073
Manufacturing	1,416	7,082	0.0029
Transportation & utilities	602	3,011	0.0046
Wholesale & retail trade	424	2,120	0.0020
Finance, insurance & real estate	194	971	0.0008
Services	672	3,358	0.0025

United States. Yet nonfatal injuries prove to be of greater consequence, because they are vastly more frequent. In the case of job-related injuries, they are so much more frequent that they constitute the lion's share of occupational health costs.

This comparatively greater role of lost workday injuries may in part be a product of the nature of social regulation in the United States. Occupational safety and health regulation enforcement is targeted primarily at eliminating fatalities, which serve as highly visible signals of risky workplaces and therefore lead to special investigations by the government. Fatalities also are more likely to be highly publicized and, as a result, will lead to a much more vigorous market response than lost workday injuries, for which information is less readily available. Thus, market forces, government regulation, and incentives generated by workers' compensation may have altered the mix of worker injuries so that the nonfatal injuries now play a much greater role in terms of the actual health costs currently borne by the nation. Future work should investigate whether the natural tendencies we identify may have produced a bias toward eliminating fatalities in our public and private risk reduction expenditures.

The net effect of the injury costs and the fatality costs as a proportion of all expenditures is summarized in table 11. Table 11a shows the cost estimates using the raw injury and fatality data in which feedback linkages are not taken into account. Table 11b shows the estimates based on the allocated risks derived from the input-output analysis.

When risk regulation entails additional expenditures by society, what are the health costs incurred? Consider the cost-share estimates for the allocated-risk data. The role of risk costs is only 1% of total industry output in the mining, insurance, and real estate industries, but reaches 4% in the construction industry. The estimates for the raw data are generally similar in character, but there are some important differences. For example, the mining industry looks almost 100% riskier if we use raw injury data instead of allocated-risk data. Even the lower-bound estimates are often nontrivial. The relative role of the risk costs is over 10% for manufacturing and almost 2% of construction expenditures. Ideally, government risk regulation policies should address the riskiness of all aspects of production, including the risks associated with creating inputs.

Table 11a. Raw injuries and fatalities per dollar of industry expenditure

Industry	Raw fatalities	Raw lost workday injuries	Midpoint* valuation ($ millions)
Agriculture, forestry & fisheries	707	69,891	7,030
Mining	315	35,724	3,361
Construction	952	344,032	21,962
Manufacturing	838	1,105,488	59,464
Transportation & utilities	901	320,518	20,531
Wholesale & retail trade	343	905,693	47,000
Finance, insurance & real estate	72	76,329	4,176
Services	545	717,132	38,582

Table 11b. Allocated injuries and fatalities per dollar of industry expenditure

Industry	Allocated fatalities	Allocated lost workday cases	Midpoint* valuation ($ million)
Agriculture, forestry & fisheries	396	67,376	5,347
Mining	103	24,036	1,718
Construction	866	407,179	24,688
Manufacturing	1,416	1,228,203	68,492
Transportation & utilities	602	250,517	15,537
Wholesale & retail trade	424	730,122	38,627
Finance, insurance & real estate	194	143,231	8,132
Services	672	724,143	39,565

*Valuations at $5 million per fatality and $50,000 per lost workday case

5. Conclusion

The occupational fatalities and injuries caused by expenditures are typically not identified within a comprehensive policy analysis. This omission is sometimes justified because it is believed that the overall cost estimates for a project reflect the wage premiums for risk. The estimates presented in this paper calculate the level of occupational risks and their economic value by industry, based on estimated implicit values of life and injury revealed in the labor market. Because the cost estimates in this paper are based on existing labor-market performance and the costs now being imposed on employers, they would be fully reflected in any cost estimates for regulatory expenditures.

There are three major reasons why compensating differentials may not adequately account for risk. First, individuals may be less than fully informed about risk levels. Second, due to moral hazard associated with a variety of social and private insurance programs, individuals may undervalue risks to themselves. Third, there may be externalities of valuation applying to health risks of others, which do not apply to their claims for other resources. (Such differential externalities may explain why governments are involved in reducing risks below the levels markets would produce.)

Risk-risk analysis requires us to break out the different health effects of expenditures. Using published risk statistics to do so is not appropriate because risks associated with producing inputs to other industries are included in these raw statistics; indeed, they are a significant component. Moreover, risks associated with the inputs to the specific industry's final product are omitted. This paper utilized input-output analysis to properly account for these relationships.

A principal consequence of proper input-output accounting is to assess more uniform risk levels across industries. High-risk industry outputs often serve as inputs to safe industries, and risky industries often utilize inputs from relatively safe industries in producing an output. The net effect is that the very risky industries turn out to be less hazardous than we thought, and apparently safe industries prove more dangerous.

The estimated risk figures provide the basis for a variety of forms of risk analysis, some of which could be included in a conventional benefit-cost approach. It is also possible to use these results in conjunction with other types of risk-risk analysis, such as ones assessing adverse risk effects resulting from the income-reduction effects of regulation. Such efforts can be thought of as part of a general effort to gain a more comprehensive perspective on the risk consequences of expenditures.

The most striking aspect of our findings is that the risks associated with expenditures are in fact quite high, particularly for nonfatal injuries. This is noteworthy given three important facts: 1) some government regulations save fewer lives and injuries per $1 million than what is created by $1 million in expenditures; 2) many statutes exclude attention to costs when considering the design of risk-reduction policies; and 3) since its inception, the U.S. Office of Management and Budget has been unable to prevent the issuance of any risk regulation with a cost-per-life-saved under $100 million.[19] Risk-risk evaluations that include the occupational risks created by regulatory expenditures may be a promising way to protect against the most profligate undertakings in the domain of risk reduction.

Notes

1. Many cleanups dramatically increase in cost as they proceed, thus calling for marginal calculations. Breyer (1993, pp. 11–12) discusses *United States* v. *Ottati & Goss*, the forced cleanup of a toxic waste dump in southern New Hampshire. The work was mostly complete, but one private party litigated the cost of cleaning up the last little bit, which would incur a cost of $9.3 million to incinerate the dirt. The parties agreed that "without the extra expenditure, the waste dump was clean enough for children playing on the site to eat small amounts of dirt daily for 70 days each year without significant harm." Burning the soil would stretch that to 245 days per year. "But there were no dirt-eating children playing in the area, for it was a swamp." The risks associated with the $9.3 million expenditure would seem to swamp those reduced by incinerating the dirt, a pattern that a risk-risk analysis would reveal.
2. Lave (1981) provides an excellent introduction to this and other forms of risk-risk analysis.
3. If workers receive compensation for a risk of $5 million per statistical life, then it is less costly to lose these lives than the original $100 million, since they are partly compensated. The $50 million payment for the 10 induced fatalities is included in the $2 billion expenditure. To avoid double counting, it should be subtracted out, yielding a net cost of $1.95 billion for saving 90 uncompensated lives. This gives a cost-per-life saved of $21.7 million.

4. We do not mean to suggest that a risk-risk test would be sufficient in a first-best world, because it ignores the monetary resources that are entailed in providing the expenditures. But to at least count risks, if that is all that allowed, is worthwhile. See Zeckhauser and Shepard (1976), which also introduces the concept of the QUALY.
5. For a detailed discussion of this form of risk-risk analysis as well as the advocacy of the input-output approach, see Lave (1981).
6. For discussion of this methodology, see Leontief (1986), the originator of this methodology, and Dorfman, Samuelson, and Solow (1958).
7. This fixed-coefficients assumption is much less restrictive than it appears, since, even with curved isoquants and labor as an input, under fairly standard conditions it will be optimal to produce as if there were fixed-input requirements per unit output.
8. Each year the U.S. Department of Commerce publishes an update of these accounts in the *Survey of Current Business*. The one for 1987 is, "Annual Input/Output Accounts of the U.S. Economy, 1987," *Survey of Current Business*, Vol. 72, No. 4, April 1992. The particular data used in this paper were obtained on a computer disk from the U.S. Department of Commerce, Economics and Statistical Analysis, Bureau of Economic Analysis.
9. See the U.S. Bureau of Labor Statistics, "Occupational Injuries and Illnesses in the United States by Industry, 1990" U.S. Department of Labor, U.S. Bureau of Labor Statistics, Bulletin 2399, April 1992. The lost workday data used for this analysis are for the year 1990, which were the most recent risk data available at the time this study was undertaken.
10. In some instances two-digit categories must be pooled to achieve comparability between the U.S. Department of Commerce input-output tables and the U.S. Bureau of Labor Statistics injury data.
11. As a cross-check, it is also useful to note that when one attempts to generate the total number of deaths and total number of injuries in the economy based on our risk estimates and the output levels of the economy, the allocated injury amounts and the raw injury amounts are equal once the output levels are converted in a manner following equation (1).
12. For a review, see Table 4-2 of Viscusi (1992), which summarizes the pertinent literature.
13. See National Institute of Occupational Safety and Health (1987).
14. The industry groupings for the risk data were needed, however, to establish the basis for aggregating industries. The level of aggregation in the input-output analysis was thus based on matching the industry groupings in the BLS risk data and the input-output data.
15. Table 4 is consequently the inverse matrix that represents the solution to the input-output system. The input matrix, which includes all of the input coefficients, is comprised of elements which are all below 1.0, thus satisfying the input-output requirements for viable products. The calculation of the inverse matrix from the input matrix was by the U.S. Department of Commerce. Dorfman, Samuelson, and Solow (1958), discuss the underlying theory; see especially Chapter 9.
16. Viscusi (1992) reviews of the literature on these issues. See especially Tables 4-1 and 4-2.
17. See Viscusi and Moore (1987).
18. The value $20,000 is in the range obtained in studies that focus on all worker injuries, including those insufficiently severe to lead to a lost workday.
19. See Viscusi (1992), Chapter 14, for a review of the efficacy of regulatory oversight.

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