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ABSTRACT

Compensating Differentials for Occupational Health and Safety Risks: Implications of Recent Evidence*

The most enduring measure of how individuals make personal decisions affecting their health and safety is the compensating wage differential for job safety risk revealed in the labor market via hedonic equilibrium outcomes. The decisions in turn reveal the value of a statistical life (VSL), the value of a statistical injury (VSI), and the value of a statistical life year (VSLY), which have both mortality and morbidity aspects that we describe and apply here. All such tradeoff rates play important roles in policy decisions concerning improving individual welfare. Specifically, we explicate the recent empirical research on VSL and its related concepts and link the empirical results to the on-going examinations of many government policies intended to improve individuals' health and longevity. We pay special attention to recent issues such as the COVID pandemic and newly emerging foci on distributional consequences concerning which demographic groups may benefit most from certain regulations.

JEL Classification: J17, I18, H40, K32, J28

Keywords: value of statistical life, VSL, value of statistical injury, VSI, value of a statistical life year, VSLY, mortality risk, morbidity risk, benefit cost analysis, hedonic labor market equilibrium, compensating wage differential, evaluation of health and safety programs

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1. Introduction

A welcome policy trend has been a general movement toward evidence-based policy. Prominent recent targets include the nuances of interventions in the Covid-19 pandemic. On the benefit side are how to evaluate the benefits of interventions to reduce morbidity and mortality. Here we demonstrate recent developments in the estimation and application of the well-known concept of the Value of a Statistical Life (VSL), which is a convenient sufficient statistic for the way to evaluate the benefit of health enhancements. Included are the connections of VSL to the health-related quantity and quality of life that involves the implicit revealed willingness to pay reductions in morbidity and mortality. We point out the underappreciated flexibility in the VSL and the related Value of a Statistical Injury (VSI) concepts that allow them to incorporate lumpiness in life duration, life-cycle effects, and economic distributional issues as well as expansions in the application of VSL to situations only recently appreciated as benefitting from the concept's application.

In what follows, we first summarize in Section 2 the theoretical and econometric underpinnings of estimating compensating differentials for health risk with a connection to the underlying individual's welfare function. Following the theoretical and econometric set-up in Section 2 we take the reader on an evidentiary tour of the set of econometric results in Section 3 that seeks to develop an appreciation for U.S. estimates of VSL and VSI based on labor market data. Applications that we present include the costs of work-related injuries and fatalities, the heterogeneity in VSL along a multiplicity of dimensions that include age, income, work-related disability insurance for health care and income losses, risk tolerance, situational risk differentials, international comparisons, and heterogeneity in VSL estimates that stem from publication bias, which is an emerging concern in empirical economics more generally. Section 4 includes the quickly emerging new applications of VSL to rules and regulations regarding military personnel decisions and government safety regulation of product characteristics and operation such as relate to motor vehicles. Another recent development in public policy involving VSL includes using it as a threshold for the point where regulatory costs are prohibitive to the point of reducing rather than enhancing safety via secondary effects as citizens reduce private-personal safety and health expenditures to fund expensive government health and safety programs. Our final topic in Section 4 is to develop the nuances of how best to use VSL and VSI estimates in economically well-grounded policy concerning widespread infectious diseases, which have so severely affected the world's economies recently. Section 5 concludes with our view of emerging issues involving VSL and its theoretical cousins.

2. Some Theoretical and Econometric Background

The fundamental model underlying what follows is that of hedonic labor market equilibrium where the labor market matches workers and jobs to produce a locus of wage-workplace characteristics (Ekeland, Heckman, and Nesheim, 2004). The focus here is on worker health and safety as related to compensation. The three-equation model that represents the demand for labor with wage/safety level pairings (which differ across firms due to cost differences), the supply of labor at each pay/workplace characteristics pairings (which differ across workers due to their different risk tolerances), and an equilibrium that is the envelope of indifference curves/isoprofit curves where S = D in each two-dimensional job situation (wage-safety level pairing).

It is relatively straightforward to estimate the hedonic locus with panel data that permit controlling for measured and latent individual heterogeneity and where workplace hazards are accurately measured (Kniesner et al. 2012, Kniesner and Ziliak 2015). The local slope of the hedonic locus is the VSL, which is the amount a worker would pay implicitly for additional safety via the hedonic labor market outcome where, cet. par., more dangerous worksites must pay more to attract labor. Other nuances include the result that workers' willingness to pay for additional safety equals workers' willingness to be paid to accept less safety (Kniesner, Viscusi, and Ziliak 2010) and the value of information on recent job changes where safety levels change (Kniesner, et al. 2012). Long-standing issues that have been additionally fleshed out recently include nonadditive functional forms and nonparametric identification (Heckman, Matzkin, and Nesheim 2010) and how to connect the hedonic locus estimates (VSL) to individual worker economic well-being at a point in time as well as over the life-cycle (Banzhaf 2020, 2021).

To fix ideas now for what is to come in the rest of our paper, the most simple representation of hedonic labor market equilibrium is the equation $w = w(p)$ where *w* is the market wage and *p* is the probability of a health hazard or health reducing injury occurring at work with the outcome that $w' = \frac{dw}{dp} > 0$, so that less (more) safe jobs pay higher (lower) wages in equilibrium all else the same. The labor market matching function between workers and jobs will most generally be nonlinear so that $d^2w/dw^2 \neq 0$. Firms with the highest marginal costs of workplace safety have the lowest safety levels and hire workers who are the least averse to incurring health risks; firms with the lowest marginal costs of making the workplace safer have the highest safety levels and hire the workers most averse to incurring health risks.

The hedonic wage equilibrium relation can be represented econometrically in a Mincer wage equation that includes job safety measures $\ln(w_{i,j,k}) = \alpha + \beta p_{i.j,k} + X_{i,j,k}\Gamma + u_{i,j,k}$, where the i^{th} worker is employed in the j^{th} industry in the k^{th} occupation. Here $\hat{\beta}$ estimates $(\frac{\partial w}{\partial p})(\frac{1}{w})$. If the risk measure *p* is scaled per *m* workers (say 100,000) then a typical calculation of the value of a statistical life is VSL = $(\hat{\beta} \times w) \times h \times m)$ using $w = \overline{w}$ and $h = \bar{h}$ (Kniesner and Viscusi 2019).

As Ashenfelter (2006) observes, ideally the conceptual experiment underlying the analysis is that the risk change is the result of an exogenous event rather than being potentially endogenous. Recent analyses using panel data have made some progress on this dimension by focusing on risk changes. Kniesner, et al. (2012) estimate the VSL based on the relationship between changes in wage rates and changes in occupational fatality rates in the worker's industry-occupation cell. Kniesner, et al. (2014) consider changes in risk levels and wages but restrict the analysis to workers who have changed jobs. Both studies estimate VSL levels in the usual range.

Studies of the VSL from outside the labor market have provided cleaner exogenous tests. Ashenfelter and Greenstone (2004) analyze the effect of mandated speed limits, which varied by state. The tradeoff yielding the VSL implied by the policy decisions was between the value of travel time and road safety. The estimated a value per fatality of $1.54 million (1997 dollars). Rohlfs, et al. (2015) use the automobile price impacts from the introduction of air bags coupled with the estimated safety benefits of the device to estimate a VSL of $10.5 million (2015 dollars).

The hedonic wage theory is in terms of the hourly wage rate with annual estimates of the average fatality risk. However, worker wealth may also affect preferences because safety is a normal good. The covariates in the wage equation sometimes include measures of worker wealth. Viscusi (1978) includes a variable for worker assets on the wage equation and finds average wage-risk tradeoffs comparable to those in specifications without the assets variable. Worker wealth is consequential in terms of the risk level that is chosen. The risk level workers select from the market opportunities locus is negatively related to worker asset levels. The dependence of the VSL on levels of consumption over the life cycle was the focus of Kniesner, et al. (2006). The VSL pattern over the life cycle exhibits a trajectory that closely mirrors the life-cycle pattern of consumption, as it rises and then falls over the life cycle. Finally, evidence on the heterogeneity of the VSL by income level as in Kniesner, et al. (2010) are consistent with more affluent workers receiving a larger amount of compensation to incur any given risk.

Recently, the concepts from behavioral economics have been applied to a wide selection of economic areas, including the value of a statistical life. Possibly the most important result is that future VSL estimates may need to consider reference group effects, reference point effects and possible differences between decision utility and experienced utility (Kniesner 2019).[1]

Finally, we will emphasize later how VSL is convenient for welfare approximations and can be generalized to include life-cycle effects such as variation in the value of statistical life year (VSLY) and the dual roles of life-cycle wealth effects and consumption plans. The issues are important for whether to use age-adjusted VSL/VSLY estimates in policy, which we develop in some detail in the next section along with the policy implications of the lumpiness implications of early death as differing from small changes in the fatality risk that produce VSL. Such distributional issues seem likely to be at the front of the components of the emerging comprehensive benefit-cost analysis of government regulations (U.S. Office of Management and Budget 2021).

[1] For more discussion and examples of including social interactions in labor market theoretical and empirical models along with some econometric results for labor supply see Grodner, Kniesner, and Bishop (2010).

3. The Evidence on Compensating Differentials for Occupational Risks

3.1 Fatality Rate Evidence: The Value of a Statistical Life

The principal focus of the empirical literature on compensating differentials has been on the wage premiums for fatality risks, which is the most severe labor market risks in terms of income and health. Wage premiums for fatality risks also play the most prominent role in the evaluation of the benefits of health, safety, and environmental regulations. As indicated above, the compensating differential per unit risk corresponds to the VSL, which is an empirical value that is widely used by government agencies throughout the world to monetize the benefit of mortality risk reductions. Data on mortality risks from illnesses caused by long-term occupational exposures has been very limited. The impediment stems from a variety of causes, including the role of long latency periods after risk exposures before illnesses become apparent, the probabilistic linkage between exposures and illnesses, and the presence of multiple potential factors that may contribute to illnesses. With rare exceptions, such as the relationship of mesothelioma to asbestos exposures, occupational illnesses are not signature diseases. So, the fatality rates in compensating wage differential studies generally pertain to traumatic injuries rather than illnesses such as cancer. Nevertheless, some of the fatalities included in the risk data, such as burn injuries, do involve prolonged periods of pain and suffering before death.

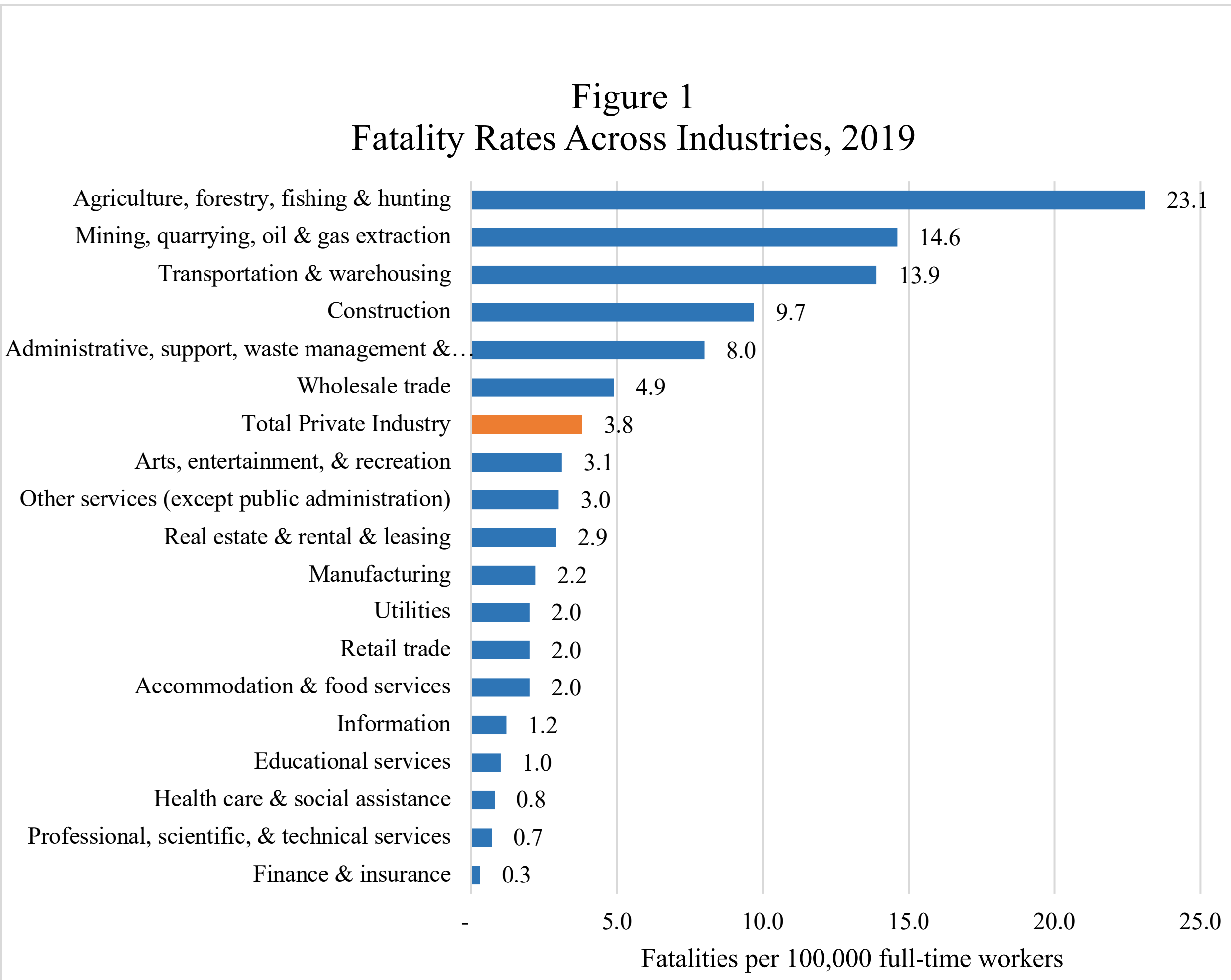
The procedure for constructing the fatality risk variable typically involves matching objective measures of job risks to workers in the sample based on one or more characteristics of the worker or the worker's job. Attributes affecting the risk level include the worker's industry, occupation, age, race, gender, immigrant status, and nature of the fatality (Viscusi 2013). The early VSL studies in the literature relied on risk measures by industry group or, in some cases, overall fatality rates for individuals in different occupations irrespective of whether their deaths were job-related. The use of broad risk measures led to critiques of the VSL literature based on substantial measurement error in the fatality risk variable, such as those by Black and Kniesner (2003) and Ashenfelter (2006). However, neither of these critiques addressed any studies based on more refined fatality risk measures that are the current norm in the literature. These refined measures also have facilitated estimates of the heterogeneity of the VSL across the labor market, making it possible to address concerns regarding the importance of heterogeneity in the VSL emphasized by economists such as Ashenfelter (2006). Heterogeneity of the VSL is the focus of Section 3.6 of our article.

Although many available fatality rate measures do not permit refined matching of job risks to workers based on multiple characteristics and may be restricted to estimates of fatality rates by industry, the U.S. Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI) includes detailed information for each individual fatality, making it feasible to construct measures of the fatality rate based on different personal characteristics and occupational contexts. Beginning with Viscusi (2004), most estimates of the VSL using the CFOI have been based on fatality rates constructed for the worker's occupation-industry cell based on 720 cells consisting of 72 industries and 10 occupational groups. Although previous studies did not examine wage premiums for risks stratified by both industry and occupation, the estimates of the VSL for the military in Greenberg, et al. (2021) use risk levels by occupation within the U.S. Army "industry."

Moreover, unlike previous U.S. measures of worker fatalities, the CFOI is a comprehensive census of job-related deaths for which the occupational linkage of the fatality is verified based on information from multiple sources, such as death certificates and workers' compensation records. Given the greater pertinence of the CFOI data as a measure of the objective job risks facing the worker the U.S. Department of Transportation (2016) bases its estimates of the policy relevant VSL exclusively on the VSL estimates using CFOI data.

Although it is feasible to construct objective fatality risk measures, many economists such as Ashenfelter (2006) have posed the question of whether workers understand the risks. Note that economic theory does not require that all workers understand the risk, as it is the preferences of the marginal worker that are most influential in setting the market wage rate. The evidence regarding the relation of worker beliefs to actual risk levels is quite strong. The first study to examine the accuracy of worker risk beliefs was Viscusi (1979), which found that estimates of the VSL were very similar whether the focus was on objective measures of fatality rates or fatality rate measures interacted with worker perceptions of the hazardousness of the job. Similarly, compensating differentials for nonfatal occupational risks were similar based on subjective and objective risk measures. These reasonable results arise because workers' job risk perceptions are based on factors that should be influential such as previous injury experiences, job characteristics such as the use of hazardous equipment, and inherently dangerous job procedures. There is also a strong overall relationship between objective measures of the injury rate and subjective risk beliefs. In a separate sample of chemical workers analyzed in Viscusi and O'Connor (1984 the subjectively assessed risk levels were equal to the objective injury rate measure for the chemical industry.

The distribution of occupational fatalities varies greatly across industries. Figure 1 presents the CFOI fatality rates per 100,000 full-time workers, by industry, for the pre-pandemic year 2019. The average annual fatality rate for private industry is 4/100,000, or 1/25,000. The most dangerous industry group is agriculture, forestry, fishing, and hunting, which has a fatality rate of 23/100,000. The next most hazardous industries are mining, quarrying, oil & gas extraction, with a fatality rate of 15/100,000, and transportation and warehousing, with a fatality rate of 14/100,000. Manufacturing jobs have fatality rates of 2.2/100,000, or about half of the private industry average. Industries such as professional, scientific, and professional services, and finance & insurance have fatality rates under 1/100,000.



Notes: Fatality rate data come from the Bureau of Labor Statistics' Census of Fatal Occupational Injuries Table A-1: Fatal occupational injuries by industry and event or exposure, all United States, 2019. Manufacturing and Information industries both use 2018 fatality rate data. Management of companies and enterprises industry fatality rate not reported because fatalities in that industry subcategory were under five. All data available at https://www.bls.gov/iif/oshcfoi1.htm#rates (under "Fatal Injury Rates").

Risk levels often very considerably by occupation within any particular industry.[2] In the case of the mining industry, workers who are handlers, equipment cleaners, helpers, and laborers, have fatality rates that are 1.8 times as great as the mining industry average. Many other mining occupations similarly have very high risks that are well in excess of the industry average. These dangerous jobs include precision production, craft and repair occupations, and transportation and material moving occupations. The mining industry also includes positions that are relatively safe occupations despite being in a generally dangerous industry. Administrative support occupations, including clerical workers, have an annual fatality rate of 0.5 per 100,000 in the mining industry. Because of these considerable differences in risk levels, many studies of compensating differentials for risk have utilized risk measures constructed using the CFOI and which are matched to workers in the sample based on both their industry and occupation.

The VSL estimates derived from estimating wage equations differ based on the fatality rate measure used, the composition of the sample, the other variables included in the model, and the econometric specification. The extent of the heterogeneity is reflected in the statistics in Table 1 drawn from Viscusi (2018a).

[2] The statistics below are based on six-year annual average CFOI statistics drawn from Viscusi (2004).

Table 1
Distribution of VSL estimates by quantile

	5%	10%	25%	50%	75%	90%	95%
All-set estimates							
Whole sample	-1.695	0.444	4.490	9.672	15.374	25.533	35.721
USA	-1.695	0.889	5.264	10.255	15.415	24.834	33.350
Non-USA	-1.782	0.038	1.097	7.144	15.272	26.123	63.182
USA CFOI	1.793	4.299	7.236	11.108	16.791	27.718	35.722
USA non-CFOI	-4.887	-1.732	0.573	4.039	12.981	24.825	24.825
Best-set estimates							
Whole sample	1.243	1.470	4.339	10.137	15.656	22.681	26.434
USA	1.470	1.922	4.551	10.176	13.458	19.192	22.681
Non-USA	0.082	1.243	3.311	7.854	20.532	25.051	39.418
USA CFOI	3.347	5.396	8.252	10.242	13.510	19.686	33.054
USA non-CFOI	1.335	1.470	3.377	9.032	13.458	19.192	22.681

Note: For the all-set sample, $N = 1025$. For the best-set sample, $N = 68$. This table is based on Table 2 from Viscusi (2018a).

The top panel of Table 1 presents VSL estimates in USD 2015 based on all of the VSL estimates included in each article (the all-set estimates). The lower panel in Table 1 draws on the single focal estimate in each article, or what are termed the "best-set estimates." The best-set and all-set samples for Table 1 consisted of VSL figures in 68 articles, which presented 1,025 estimates of the VSL. Although government agencies frequently focus on the best estimate from each article, doing so induces statistically significant publication selection effects (Viscusi 2018a). For both the all-set estimates and the best-set estimates, Table 1 reports VSL figures for different estimation groups: all studies based on U.S. employment and fatality data, estimates from countries other than the U.S., U.S. estimates based on the CFOI fatality rate measure, and U.S. estimates based on fatality rate measures other than the CFOI.

Consider the U.S. estimates using the CFOI. Based on the all-set sample, the median VSL is \$11.1 million, with a range from \$7.2 million at the 25th percentile to \$16.8 million at the 75th percentile. The all-set estimates are more tightly compressed, as authors are less likely to select estimates out of line with previous studies in the literature as their best estimate. The median

VSL is $10.2 million, with a 25th percentile value of $8.3 million and a 75th percentile of $13.5 million. For purposes of calculating the monetized value of mortality risks below, we adopt a figure of $11 million in USD 2019, which is consistent with the bias-adjusted estimates using the all-set results.[3]

The VSL figure above is a bit higher than the widely cited estimates in Viscusi and Aldy (2003), which had a median value of $7 million in $2000, or a value of $10.3 million in USD 2019. However, the estimates just mentioned were based entirely on studies using fatality rate data before the adoption of the CFOI in the literature. The values also were not adjusted for publication selection effects. The median CFOI value in Table 1 that is the most direct counterpart to the earlier Viscusi and Aldy (2003) estimate is the median $10.2 million VSL in USD 2015, or $11.1 million in USD 2019, which is about $1 million higher.

Given the greater affluence of the U.S. as compared to the rest of the world, one would expect the U.S. VSL estimates to be greater than almost all other countries. The median non-USA VSL in the all-set estimates is $7.1 million, and for the best set estimates the median non-USA value is $7.8 million. Pooling the results for the USA sample and the estimates for other countries in the world yields a median VSL of $9.7 million for the all-set results and $10.1 million for the best-set estimates. While the lower VSL estimates outside of the U.S. accord with expectations given the pronounced differences in per capita income as compared to the U.S., there is evidence that the extent of the estimated difference may understate the difference in the VSL levels reflecting the risk preferences in different countries. Because estimated VSL figures for the U.S. studies establish a reference point with regard to reasonable estimates that merit submission to journals and publication in the literature, there is evidence of substantial

[3] This converts the $10 million bias-adjusted estimate in USD 2015 in Viscusi (2018b) into current dollars.

publication selection biases undermining the validity of international studies of the VSL, as we discuss below.

3.2 Injury Rate Evidence: The Value of a Statistical Injury

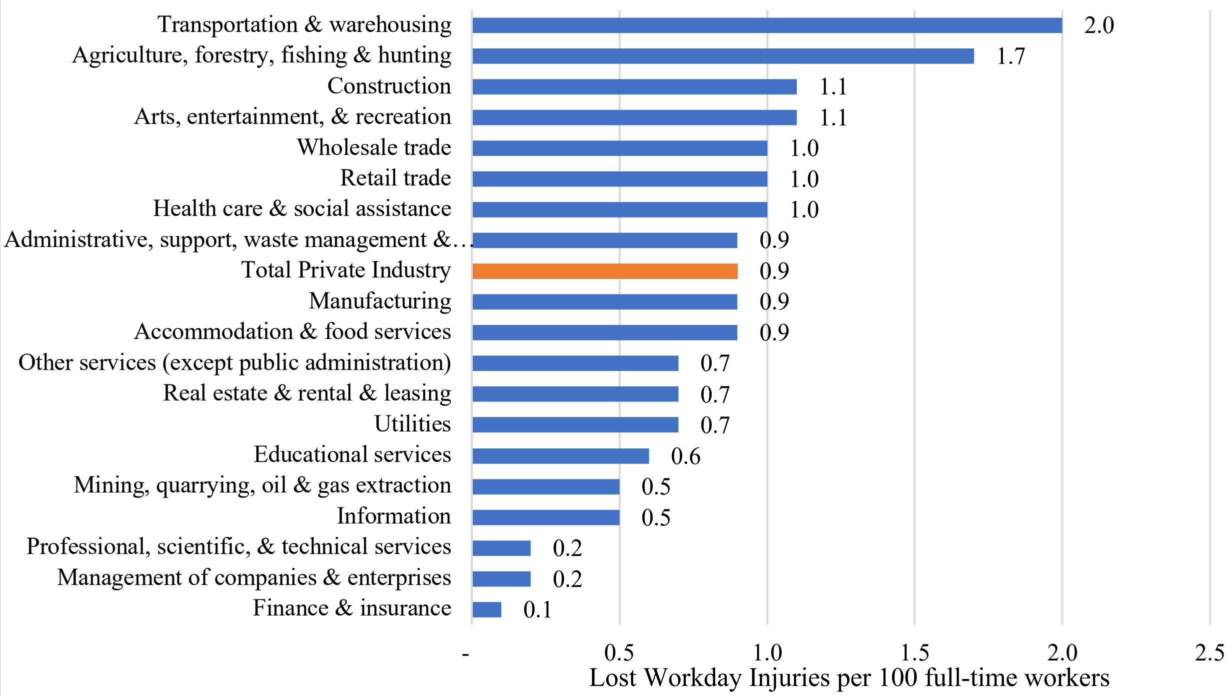
In much the same way that it is feasible to estimate the VSL based on wage-fatality rate tradeoffs, it is also feasible to estimate the value of a statistical injury (VSI), which is constructed analogously. Unlike fatalities, which are well-defined events, injuries differ in relative severity. What is meant by the VSI depends on the way in which injuries are categorized. Broad injury characterizations such as an overall measure of whether a worker experienced a job injury may raise classification problems. It may be unclear whether a particular on-the-job injury is sufficiently severe to constitute an injury, and employers may differ in their vigilance in reporting minor injuries. Some injuries may require only minimal medical treatment with no loss of work. Other injuries could be permanently disabling. The 2019 injury frequency rates per 100 full-time workers for all private industries and government entities was 3.0 for all recordable cases, of which 0.9 involved cases with days away from work, 0.7 involved days of job transfer or restriction, and 1.4 did not involve any days away from work, job restriction, or transfer.[4] The injury characterization that has formed the basis of many recent empirical analyses is the frequency of injuries that are sufficiently severe to lead to a lost workday.

Figure 2 provides a summary of the lost workday injury rates by industry. It is the nonfatal risk counterpart of Figure 1. Two of the highest fatality rate industries also have higher nonfatal risk levels, but their order is reversed. The nonfatal risk level per 100 full-time employees in transportation and warehousing is 2.0, which is just above the rate of 1.7 for

[4] These statistics are from U.S. Bureau of Labor Statistics, Injuries, Illnesses and Fatalities, Table 1 Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2019. https://www.bls.gov/web/osh/summ1_00.htm.

agriculture, forestry, fishing and hunting. Mining, quarrying, and oil and gas extraction had the second highest fatality rate but have a lost workday injury rate that is only just over half of the national average injury rate and well below seemingly safer industries such as arts, entertainment, and recreation. Many industries have injury rates around the national average, and there are some very low injury rate industries such as finance and insurance.

Figure 2
Lost Workday Injury Rates Across Industries, 2019



Notes: Lost workday injury rate data come from the Bureau of Labor Statistics' November 4, 2020, report, "Employer-Reported Workplace Injuries and Illnesses (Annual) News Release" Table 1: Incidence rates of nonfatal occupational injuries and illnesses by selected industry and case types, private industry, 2018-19, available at https://www.bls.gov/news.release/osh.htm. Administrative, support, waste management & remediation services uses 2018 injury data.

Viscusi and Aldy (2003) provide a review of 31 VSI studies in the U.S. and 8 VSI studies based on labor market estimates from other countries. The studies varied in terms of the risk measure employed, including the overall injury rate, the rate of injuries involving at least one lost workday, and the rate of total lost workdays, which captures the duration of the injury effects. Estimates also varied depending on other risk-related variables in the model. For example, was a workers' compensation benefit variable included in the wage equation, where this measure sometimes is often based on an interaction of the benefit levels with the injury rate in order to calculate the expected workers' compensation benefits. Because of these differences in equation specification, it is more difficult to synthesize the results to obtain an average estimate of the VSI. The U.S. VSI range in Viscusi and Aldy (2003) was $20,000 to $70,000 in USD 2000. Some international estimates in their review were within that range and some were at lower levels. However, there is a consensus based on this review that nonfatal injury risks do command compensating differentials far below the VSL.

Several recent estimates of the VSI have reported results based on equations including a fatality rate variable as well as a measure of nonfatal injury rates. The most conventional specification is that in Viscusi and Gentry (2015), which included the CFOI fatality rate and the lost workday injury rate. Their research yielded a VSI level from $79,000 to $81,000 in USD 2008, depending on whether the fatality rate measure was calculated on an hours-adjusted basis. Below we use the midpoint estimated value of $80,000, or $98,000 in USD 2019, to calculate the value of lost workday injuries.[5]

3.3 Economy-Wide Fatality and Injury Costs

Based on the average estimates of the VSL and the VSI, it is feasible to calculate the total compensating differentials received for the two types of risks. The values also serve as measures of the mortality and nonfatal injury costs of job risks to the economy. Table 2 presents the components of this calculation by industry and for total private industry. In 2019 there were

[5] The estimated VSI in Viscusi (2004) is lower because it also included interactions of the lost workday injury rate with workers' compensation benefit levels. The estimated VSIs in Gentry and Viscusi (2016) were higher, but these were based on a model in which the morbidity effect of fatalities was also included in the analysis along with the fatality rate.

4,907 occupational fatalities, which have a monetized value of $54 billion. Lost workday injuries are much more frequent, resulting in an $87 billion value for the 888,200 lost workday injuries. The total monetized value of fatal plus nonfatal occupational risks is $141 billion, of which 38% is the mortality cost share.

Table 2
The Level and Monetized Costs of Occupational Fatalities and Injuries

Industry	Fatalities	Fatality Costs	Lost Workday Injuries	Injury Costs	Total Costs	Fatality Cost Share
Total Private Industry	4,907	53,977	888,200	87,044	141,021	0.38
Agriculture, forestry, fishing and hunting	573	6,303	17,000	1,666	7,969	0.79
Mining, quarrying, and oil and gas extraction	127	1,397	4,200	412	1,809	0.77
Utilities	22	242	3,700	363	605	0.40
Construction	1,061	11,671	79,700	7,811	19,482	0.60
Manufacturing	343	3,773	116,100	11,378	15,151	0.25
Wholesale trade	178	1,958	55,500	5,439	7,397	0.26
Retail trade	291	3,201	120,200	11,780	14,981	0.21
Transportation and warehousing	913	10,043	103,600	10,153	20,196	0.50
Information	31	341	13,000	1,274	1,615	0.21
Finance and insurance	21	231	7,500	735	966	0.24
Real estate and rental and leasing	87	957	14,900	1,460	2,417	0.40
Professional, scientific, and technical services	86	946	17,200	1,686	2,632	0.36
Management of companies and enterprises	3	33	4,700	461	494	0.07
Administrative and support and waste management and remediation services	498	5,478	46,500	4,557	10,035	0.55
Educational services	45	495	12,100	1,186	1,681	0.29
Health care and social assistance	152	1,672	151,400	14,837	16,509	0.10
Arts, entertainment, and recreation	83	913	15,300	1,499	2,412	0.38
Accommodation and food services	188	2,068	82,900	8,124	10,192	0.20
Other services (except public administration)	210	2,310	21,800	2,136	4,446	0.52

Notes: Fatalities and lost workday injuries are in 2019. The VSL is $11 million, and the VSI is $98,000. All figures are in USD 2019. Manufacturing and Information industries both use 2018 fatality data. Management of companies and enterprises industry uses 2017 fatality data. Administrative and support and waste management and remediation services uses 2018 injury data. The correlation between fatalities and lost workday injuries across industries is 0.96.

For fatalities and lost workday accidents, the construction industry and the transportation and warehousing industry head the list, but their order is reversed in the two categories of fatal injury costs and nonfatal injury costs. The role of fatalities as measured by the fatality costs share of risk compensation is particularly dominant for two industry groups -- agriculture, forestry, fishing and hunting, and mining, quarrying, and oil and gas extraction. In each case, almost four-fifths of total injury costs are comprised of the fatality-related costs.

3.4 Morbidity Effects and the Nature of the Fatality Risk

Occupational deaths vary in terms of the circumstances of the fatality and the morbidity effects that are incurred before death. Although all fatal injuries lead to the loss of life, the welfare consequences are not identical in each instance. Moreover, because compensating differentials stem from expectations regarding the risks, the worker's awareness of influences such as being exposed to death from violent attacks or hazards that involve painful burn injuries will also contribute to the observed compensating differential. Fatal job injuries are typically not painless and instantaneous, so they also embody a morbidity component not unlike that associated with job injuries.

Consider the following components of the VSL using a compensating differential model similar to that in Gentry and Viscusi (2016). As above, p is the fatality risk, $w(p)$ is the wage rate for facing risk p, $u(w(p))$ is the utility if not injured, and $v(w(p))$ is the bequest function after death. Let the morbidity component associated with a fatal injury be an additive component in the post-injury state. Thus, the addition to the standard model is a term $z(w(p))$ that has a negative value, so that the utility function after a fatal injury is given by $v(w(p)) + z\,(w(p))$.

Following the usual optimization in which the worker selects the value of p that maximizes expected utility, produces the result that

$$VSL = \frac{dw}{dp} = \frac{u - v - z}{(1-p)u' + p(v' + z')}. \tag{1}$$

If the morbidity component z is not dependent on the compensation for risk, then the VSL amount implied by the inclusion of morbidity effects only differs from the inclusion of the -z term in the numerator this equation, which boosts the VSL for painful morbidity effects with the negative z.

It is feasible to compartmentalize the VLS into the loss of life component and the morbidity component. The loss of life component of the VSL is designated the value of fatality risk (VFR), and the morbidity component of the VSL is the value of morbidity risk (VMR). These components are given by

$$VFR = \frac{u - v}{(1-p)u' + p(v' + z')}. \tag{2}$$

and

$$VMR = \frac{-z}{(1-p)u' + p(v' + z')}. \tag{3}$$

Using CFOI data that takes into account the duration of medical treatment following the fatal incident, Gentry and Viscusi (2016) estimate that the VMR component of the VSL ranges from 6% to 25% depending on the injury category.

Estimates of the VSL for particular types of deaths will embody both VFR and VMR components, thus providing a theoretical rationale for some of the heterogeneity in VSL levels that has been observed across different studies. Violent deaths such as those resulting from assaults involve morbidity components that are analogous to pain and suffering in terms of how they would enter the model above in terms of their economic structure. Using CFOI data, Scotton and Taylor (2011) find that violent deaths from assaults generate different VSL levels than do deaths that do not involve this additional threat component. This result is also borne out within occupational groups. In an analysis focusing on occupational drivers, Kochi and Taylor (2011) find that violent deaths command a VSL level that is significantly different than for fatality risks without this additional component.

3.5 Compensating Differentials for Risk-Related Benefits

Provision of other job benefits or risk-related amenities should affect the attractiveness of the job and may also affect the willingness to incur occupational risks. For example, if all financial losses and medical costs are addressed through workers' compensation programs or health insurance, then that aspect of the job injury will not be as consequential. The worker will still incur any related pain and suffering and long-term disability but will be free of many of the financial hardships accompanying job injuries.

In the case of workers' compensation, more generous benefits provided after worker injuries lead workers to accept lower wages for hazardous jobs (Viscusi and Moore 1987). That there should be a wage offset follows directly from basic economic theory. The magnitude of the offset is also of economic interest. If workers are risk-averse, then they will value workers' compensation benefits as being worth more than their actuarial value. These benefit programs will be particularly attractive if the administrative costs of operating the workers' compensation program are low, as they are for the U.S. workers' compensation system, where the administrative cost share is about 20% of the premium amount. The net result is that the estimated wage offset for workers' compensation exceeds the cost of the benefits to the firm so that, in effect, the workers' compensation program pays for itself from the standpoint of the firm.

Health insurance programs are less directly tied to work injuries than is the workers' compensation program, but one would expect to find wage offsets for these benefits as well. However, the evidence regarding the wage effects of health insurance is more mixed. Given the positive income elasticity of the demand for health insurance, the wage effect estimates are often difficult to estimate empirically and have led to a large literature. The following articles are representative. Gruber (1994) found that the costs to the employer of the Pregnancy Discrimination Act of 1978 were fully shifted to workers, consistent with the effect of workers' compensation program. However, analyses of the wage effects of health insurance coverage have not generated such unambiguous results. Baicker and Chandra (2005) used medical malpractice payments as an instrument for health insurance premiums, finding a negative but not statistically significant relationship to wages. Similarly, Buchmueller, DiNardo, and Valletta (2011) did not find any statistically significant impact on wages of the expansion of Hawaii's Prepaid Health Care Act.

3.6 Heterogeneity of the VSL

3.6.1 Income

More affluent workers will be less willing to work on dangerous jobs because of the positive income elasticity of the valuation of health. The variation in the VSL with income will also result because workers with relatively low individual levels of VSL will be more likely to be sorted into very dangerous jobs. How the VSL varies with income is of policy relevance. Government agencies frequently rely upon the income elasticity when periodically updating the agency's VSL figure to account for changes in societal income levels and for applying VSL estimates to populations that might have quite different preferences than the average worker. Given the continuing prominence of the relationship of the VSL to income, there have been several research strategies that have been adopted to estimate the income elasticity.

The first approach is that of a meta-analysis in which VSL estimates from different studies are pooled. The researchers then estimate the relationship of the VSL to average income levels of the workers in the sample, controlling for other differences in the studies, such as the particular fatality risk dataset used and whether the study included a workers' compensation variable. The estimated elasticities were 0.53 in Liu, Hammitt, and Liu (1997), 0.89 in Miller (2000), 0.46 in Mrozek and Taylor (2002), and 1.66 in Bowland and Beghin (2001). A replication of these analyses based on the authors' regression specification but using a larger VSL dataset in Viscusi and Aldy (2003) generated income elasticity estimates of 0.51 to 0.61. Estimates with this large VSL dataset but using a more comprehensive set of control variables and different estimation techniques similarly yielded income elasticity estimates ranging from 0.5 to 0.6.

The second approach to estimating the income elasticity of the VSL is to undertake a meta-regression analysis that accounts for publication selection effects that affected which empirical results are submitted to journals and ultimately published. The first such study that adjusted for publication selection effects was the meta-analysis by Doucouliagos, Stanley, and Viscusi (2014). Their meta-regression used a sample of 101 estimates drawn from 14 published meta-analyses. Based on the most precisely estimated income elasticity of the VSL values, the authors found a VSL income elasticity range of 0.61 to 0.62. Drawing on a large international sample of VSL estimates, Viscusi and Masterman (2017) estimated a VSL income elasticity range from 0.5 to 0.7 for the U.S. and 1.0 for studies outside the U.S. Similar differences between the income elasticity of the VSL in the U.S. and the higher income elasticity of the VSL in other countries are also apparent in the counterpart meta-analyses for stated preference studies in Masterman and Viscusi (2018a, 2020). For these international studies, the authors found that the income elasticity of the VSL varied depending on the per capita income in the country and was lower for less developed countries.

The third approach to estimating the income elasticity of the VSL is to use a single U.S. employment sample and to analyze how the income elasticity of the VSL varies across the wage distribution for a sample in a single year based on a quantile regression analysis. The article by Kniesner, Viscusi, and Ziliak (2010) analyzed a single year of the Panel Study of Income Dynamics coupled with the CFOI fatality rate data, yielding an average income elasticity of 1.44. Based on the quantile regression analysis, the income elasticity varies across the sample from a high value of 2.2 at the 10th percentile of the distribution to 1.2 beginning at the 75th percentile. The decline in the U.S. income elasticity of the VSL as one moves to workers in higher wage groups parallels the decline in the international income elasticity for more affluent countries.

The fourth estimation approach by Costa and Kahn (2004) uses the change in U.S. income levels over time to examine how the VSL has changed from 1940 to 1980. Their study relied on fatality rate data before the advent of the CFOI, which is consistent with the procedure used in the early VSL literature. Their estimated income elasticity was a range from 1.5 to 1.7.

3.6.2 Age and the Value of a Statistical Life Year

The theoretical underpinnings of the VSL are intrinsically linked to age. The lifetime welfare implications of fatality risk necessarily depend on how much of the life is at risk. Overall estimates of the VSL provide information on tradeoffs between wages and risk for the average life expectancy of workers in the sample. There are two general approaches that have been taken to examine in greater detail the role of life expectancy at risk—estimates of the VSL by age and estimates in which the main risk variable of interest is not the fatality rate but the discounted expected number of life years at risk.

Although age has always played a central role in theoretical explorations of the VSL, the early empirical explorations of age effects were hindered by the absence of fatality risk measures that did not reflect the average risks for workers in different age groups. The jobs on which they work are different, and for any given occupation the likelihood of incurring a fatal injury is also age dependent. Because a large share of occupational fatalities are attributable to transportation-related accidents, it is not necessary for older workers to be doing physically demanding entry level jobs in order to be exposed to risks. Deaths from falls also increase with age. For particular lines of work based on the worker's industry, older workers in the age 55-62 range consistently have higher fatality rates than workers aged 20-24 (Viscusi and Aldy 2007). The VSL is not simply an academic issue pertinent to researchers' understanding of the risk tradeoffs for younger workers. The role of age in influencing the VSL is also of policy relevance as government agencies often must monetize very modest extensions in life expectancy. Using a VSL to assign a monetary value to life expectancy gains of only a year or less of remaining life expectancy raises questions about the appropriateness of using VSL to measure of the benefit of a small change in life expectancy.

The more pertinent age-specific estimates of the VSL began to emerge in the literature after the advent of the CFOI data and the ability to construct fatality rate measures for workers in different age groups, also considering possible other factors such as the worker's industry and occupation. A series of articles have used the age-specific CFOI to examine the age dependence of the VSL in a meaningful way (Kniesner, Viscusi, and Ziliak 2006, Viscusi and Aldy 2007, Aldy and Viscusi 2007, Aldy and Viscusi 2008, Viscusi and Hersch 2008, and Aldy 2019). The principal result of research is that in the labor market the VSL displays an inverted U-shaped relationship with age. The VSL rises over time and then declines in workers' 40s but does not plummet with age. The estimated VSL for workers in their early 60s is consequently higher than that for workers in their early 20s, who have much greater life at risk.

This inverted-U shape relationship plays a prominent role in labor economics generally with respect to the life-cycle pattern of earnings. Johansson (2002) developed the economic analysis of the theoretical relationship between personal consumption and the VSL, each of which follows a similar pattern of rising and then falling over the life cycle. The empirical linkage between consumption levels and the age-specific VSL is documented in Kniesner, Viscusi, and Ziliak (2006).

The age variation in the VSL and the desire to monetize small changes in mortality risk has led to the development of the value of a statistical life year (VSLY). In particular, let *r* be the rate of interest and *L* be the worker's life expectancy, then the relationship developed in Moore and Viscusi (1988) is that

$$VSL = \frac{VSLY}{r} - \frac{1}{(1+r)^L}\left[\frac{VSLY}{r}\right]. \tag{4}$$

Then this equation can be rewritten as

$$VSLY = \frac{rVSL}{[1-(1+r)^{-L}]}. \tag{5}$$

A series of articles in Moore and Viscusi (1988,1990a, 1990b), Viscusi and Moore (1989), and Scharff and Viscusi (2011) has also estimated the implicit discount rate r that workers use in valuing the discounted value of the life expectancy at risk. While some estimates of *r* are relatively low, many of these estimates are in the 10% range, as are estimates for hedonic pricing models for discounted expected years of life for consumer purchases of used cars, as reported in Dreyfus and Viscusi (1995).

The relationship of the VSL and the VSLY has led some authors of age-VSL articles to also present estimates of the VSLY. The VSLY exhibits an inverse-U shaped pattern, as does the VSL, but it peaks at a somewhat later age than does the VSL. Assuming a real discount rate of

3%, which is consistent with the government's social rate of discount, estimates of the VSLY are often in the range of $400,000 to $500,000 in USD 2015 (Viscusi 2018b).

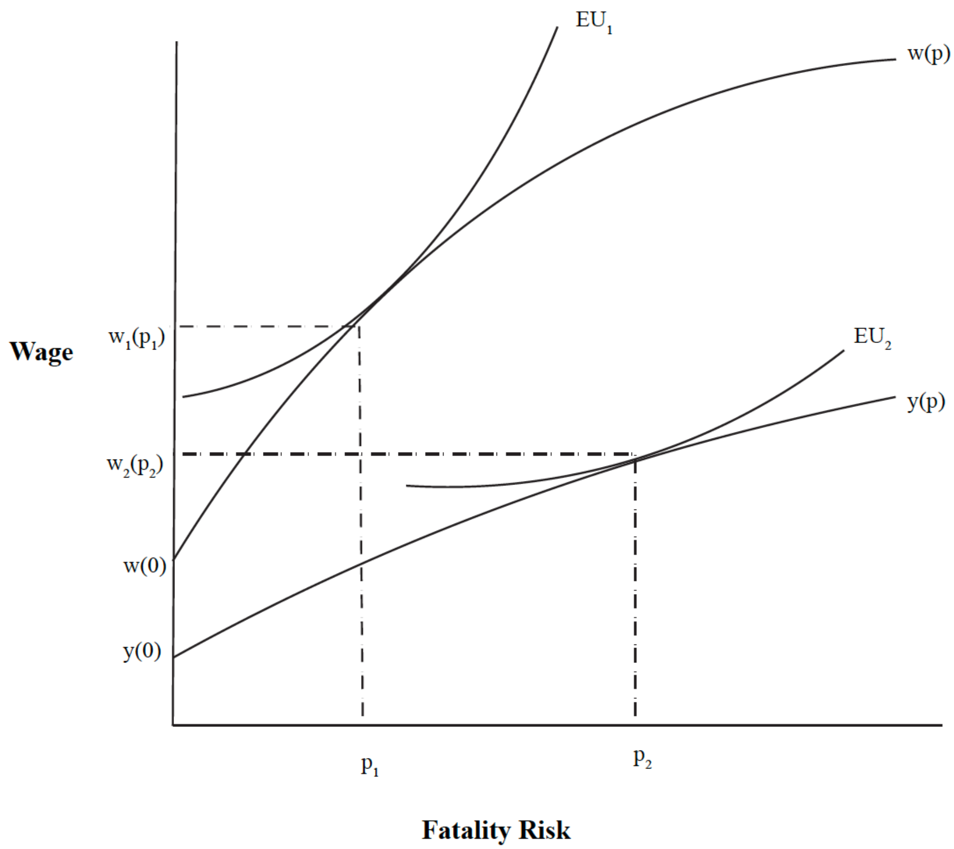
3.6.3 Segmented Labor Markets: Smoking, Race, and Immigrants

The basic textbook figure for hedonic wage models shows an offer curve available to workers, where different workers select different wage-risk combinations from their market opportunities. The hedonic wage equation fits a curve to the various points of tangency of worker indifference curves and the market opportunities. Often the market opportunities locus available to workers may be quite different, leading to observed heterogeneity in the estimated VSL.

The original model of the phenomenon of demographic differences in hedonic equilibrium wage loci developed by Viscusi and Hersch (2001) focused on the different labor market performance of labor markets for the compensation that smokers and nonsmokers receive for nonfatal injury risks. Smokers tend to be more injury prone generally than are nonsmokers, so that there may be legitimate safety-related productivity differences based on smoking status. There also could be misperceptions of these productivity differences in this and in other contexts in which there is different treatments of employee groups.

Consider the following figure in which there are two market offer curves.

Figure 3



The horizontal axis is the fatality rate, and the vertical axis is the wage rate. The market offer curve for nonsmokers is given by $w(p)$. The offer curve for smokers is $y(p)$, which is lower and flatter than $w(p)$. Worker 1 selects the risk p_1 that offers a wage $w_1(p_1)$, and the smoker worker 2 selects the risk p_2 and is paid $w_2(p_2)$. Compare the situations for the nonsmoking and smoking workers. Worker 1 has a higher VSL than does worker 2 as evidenced by the difference in the slopes of the market offer curves based on their job choice. The compensating differential for risk that is received by nonsmoking worker 1 is $w_1(p_1) - w(0)$. The counterpart compensating differential for smokers is $w_2(p_2) - y(0)$. The empirical results for nonfatal job injuries reported in Viscusi and Hersch (2001) found that smokers incur greater labor market risks than nonsmokers and receive less risk compensation for these risks, which is consistent with the segmented labor market model. The idea that there may be dual labor markets or segmented markets arises in other labor economics contexts as well, such as with respect to internal labor markets (Doeringer and Piore 1971).

Similar labor market segmentation is evident in other market risk contexts, notably with respect to racial differences and immigrant status. Applying the same approach as above, it is possible to identify other labor market groups that are exposed to relatively greater risk but receive less compensation for these risks than counterpart labor market groups. This segmented labor market phenomenon is consistent with the VSL evidence by race, as Black workers incur greater fatality risks than white workers but receive less compensation for these risks (Viscusi 2003). The inadequate compensation that Black workers receive for fatal and nonfatal risks is also documented in the article by Leeth and Ruser (2003). Immigrants similarly may be disadvantaged. Hersch and Viscusi (2010) found that legal Mexican immigrants receive less compensation for larger risks than do native U.S. workers. The gap for fatality risk compensation is especially pronounced for immigrants who are not proficient in English.

3.6.4 High Risk Occupations: The Military and Fisheries

One potential source of heterogeneity arises as individuals who are more willing to bear risk will tend to sort themselves into higher risk occupations. By willing to accept these jobs for less hazard pay than others may require, they will have revealed their lower VSL through their job choices. This sorting process will give rise to observed heterogeneity in the VSL in the workplace. Two high risk occupations that have been the subject of labor market analyses are members of the armed forces and fisheries occupations.

The first detailed exploration of the rates of risk tradeoff for those in the military was the study by Rohlfs (2012). His analysis of decisions made during the Vietnam War era took two complementary approaches. Based on college enrollments to avoid the draft, Rohlfs (2012) estimated that prospective soldiers had a VSL in the \$1.6 million to \$5.2 million range. Using military enlistment decisions, he estimated a VSL range from \$7.4 million to \$12.1 million.

A more current analysis of military compensation has focused on pay provided to the military deployed in Iraq and Afghanistan by Armey et al. (2021). Members of the military who were deployed in Iraq and Afghanistan incurred fatality risks that were 15 times the national civilian workforce average, or a greater risk of 45/100,000 for those who are deployed compared to the fatality rates of those in the military who are not deployed in combat areas. This fatality rate is higher than the industry averages shown in Figure 1. However, some occupations such as logging and work in the fisheries industry do pose greater fatality risks than military deployment. The authors estimate that the military who are deployed in combat areas should receive an extra \$861 per month average pay premium, but the current premium is \$1230 per month.

The study of worker decisions in the U.S. Army by Greenberg, et al. (2021) takes a different approach. Instead of focusing on wage rates, it analyzes the discrete reenlistment decision in response to wage bonuses. The estimated tradeoff rate is that between retention bonuses and mortality risks. They estimate an average VSL between \$500,000 and \$900,000.

The fisheries industry has long been one of the most dangerous worker pursuits. To explore the extent to which there are compensating differentials for these risks, Shnier, Horrace, and Felthoven (2009) coupled estimates of daily revenues per fishing trip based on Alaskan vessel landings data with fatality data from the National Institute of Occupational Safety and Health, Alaska Field Station. Their estimates of the VSL ranged from \$4.00 million to \$4.76 million in USD 2007.

Lavetti (2020) also estimated the compensating differentials received in the Alaskan fishing industry. The wage data were based on a self-conducted survey of deckhands working in Bering Sea fisheries, and the fatality data were from the Alaska Occupational Injury Surveillance System. The fatality rate entered the equation in a nonlinear manner. The marginal VSL calculated at a fatality rate of 1/1,000 was $12.6 million, but after controlling for unobserved worker, firm, and match heterogeneity, the estimated marginal VSL is $6.6 million in USD 2009.

3.6.5 Other Sources of Heterogeneity of Compensation for Job Risks: Gender and Unions

Women often work on dangerous jobs, but generally do not incur fatality rates that are comparable to those of men. However, there is strong empirical evidence that women face sometimes large risks of nonfatal injuries and receive compensating differentials for these risks. The first study to examine this relationship was Hersch (1998). A major strength of the study is that it used gender-specific injury rates by industry and by occupation. She found that 2-3 percent of female workers' wages were accounted for by the average nonfatal risk that these worker face, or about $400 to $563 per year. The estimated VSI was $20,000 based on industry rates and $30,000 based on occupational rates.

Estimating comparable VSL estimates for women is more challenging given the relative infrequency of occupational fatalities for women. The estimates in Viscusi (2004) based on average overall industry-occupation fatality rates led to estimates of the VSL of $7.0 million for blue-collar men and $8.5 million for blue-collar women in USD 1997. Other studies have found lower estimated VSL figures for women, where the differences are driven by the lower average wage level for women, which enters linearly in the VSL formula for a semi-logarithmic wage equation. For example, using gender-specific fatality rate data, Viscusi and Hersch (2008) estimated a VSL of $8.5 million for male nonsmokers and $8.1 million for male smokers, and for women a VSL of $6.4 million for both smokers and nonsmokers, where all figures are in USD 2000.

Historically, unions have played an important role in fostering compensation for job risks. Unlike individual workers, labor unions should be better informed about job risks and are able to communicate risk information to workers (Viscusi 1979, Olson 1981). Unions are also engaged in dealing with worker grievances and often serve a liaison role with visiting occupational safety inspectors. Unions also can potentially bargain on behalf of all workers, including the infra-marginal workers whose preferences otherwise might not be fully represented (Viscusi 1980). Workplace safety also may be a quasi-local public good that will be underprovided given collective action free riding problems (Dillingham and Smith 1984).

The review of the union-compensating differential literature by Viscusi and Aldy (2003) found stronger evidence of union effects on compensating differentials in studies of the U.S. labor market than in international studies. Of the 10 studies with estimates of the union effects on compensation for fatality rates, 8 found higher VSL levels for unionized workers, with the others finding no statistically significant differences. Much the same result held for nonfatal injuries, as the VSI was greater for unionized workers than non-unionized workers in 4 of the 6 studies analyzed. For the 14 international studies of the VSL, 5 studies found higher VSI levels for unionized workers while 2 found lower VSI values, with most of the studies indicating no consequential differences. Unions appear to have been more protective of workers with respect to traditional safety risks than they are with respect to risks from COVID-19, for which risk reduction measures include precautionary behaviors by workers such as vaccinations, masks, and testing.

3.6.6 International Differences in the VSL

Given the international differences in income, levels of economic development, and societal attitudes toward health risk, it is not surprising that there would be substantial differences in the estimated VSL across countries. An additional complicating factor is that the data needed to undertake labor market estimates of VSL may not be available for all countries. A principal shortcoming is that there is no international counterpart of the CFOI data, as the fatality data from other countries varies in its quality.

As the statistics in Table 1 indicated, based on the all-set estimates the international VSL for countries other than the U.S. has a median value of \$7.1 million, with a 25th percentile value of \$1.1 million and a 75th percentile value of \$15.3 million. Using the best-set estimates, the VSL has a median value of \$7.8 million, a 25th percentile value of \$3.3 million, and a 25th percentile of \$20.5 million. The median estimated values are below those estimated in the U.S., which is reflective of the positive income elasticity of the VSL. The international estimates also reflect a greater degree of variance compared to the U.S. estimates, as the non-US VSL best-set estimates exceed those for the USA for the 75th, 90th, and 95th percentiles, and are below the USA estimates at the 5th, 10th, and 25th percentiles.

The estimated VSL also differs based on the source of the fatality rate data. The meta-analysis by Viscusi and Masterman (2017a) identified 23 international labor market studies that relied on government data to construct estimates of the VSL. The governmental data sources differed across countries and included data from labor-related agencies (e.g., Japan's Ministry of Labor's Yearbook of Labor Statistics), workers' compensation statistics (e.g., Quebec Compensation Board Data Bank), and government census information (e.g., the U.K. Office of Population Censuses and Surveys Occupational Mortality Decennial Supplement). Relying on these diverse data sources, these articles yielded estimates that had a median VSL of $6.9 million, a 25th percentile value of $1.0 million, and a 75th percentile value of $15.4 million, where all estimates are in USD 2015. In the case of 3 studies, the researchers used non-governmental data from insurance companies: the Swiss National Accident Insurance Company, Statutory Accident Insurance Corporations in Germany, and three Austrian insurance companies. The studies based on non-governmental statistics led to a median VSL of $9.8 million, a 25th percentile value of $7.0 million, and a 75th percentile value of $11.6 million.

The international income elasticity of the VSL is just above 1.0. Coupling this income elasticity value with the Gross National Income (GNI) per capita and the U.S. estimate of the VSL leads to an average VSL of $107,000 in World Bank lower income countries, $420,000 in lower-middle income countries, $1.2 million in upper-middle income countries, and $6.4 million in upper income countries (Viscusi and Masterman 2017b). An alternative to extrapolating the U.S. estimates to other countries using the VSL, the income elasticity, and GNI levels per capita is to use country-specific estimates of the VSL, but that may be problematic due to data limitations and publication selection biases.

3.7 Publication Selection Effects

There may be substantial biases with respect to which research results are submitted to journals and which findings are published. Much of the concern with potential biases of this type emerged in the literature dealing with the publication of results from randomized control trials for health care interventions (Dwan, et al. 2008). Medical researchers are more likely to publish results that indicate favorable findings and results that are statistically significant. Influences that may be present include the role of financial incentives and the lure of exciting new results, but these findings are frequently refuted in subsequent research (Ioannidis 2005).

Although economic researchers do not face the same degree of competitive pressures and financial incentives as do medical researchers, the same types of influences that generate publication selection effects in medical research also generate biases that have been found in many areas of economic research. A particularly striking example is that Doucouliagos, Stanley, and Giles (2012) estimated that correction for publication selection biases reduces the VSL by 70-80% to a value of about $1.1 million. If these reductions were to be adopted in government policy analyses, it would have a profound effect on the evaluation of the mortality reduction benefits and ultimately on the desirability of different policy interventions.

To explore the role of publication selection effects, Viscusi (2015) used both a sample of studies that utilized the CFOI fatality rate data as well as the sample in the analysis by Doucouliagos, Stanley, and Giles (2012). The VSL in the CFOI sample had a mean value of $14.0 million and a median value of $11.3 million, in USD 2013. No statistically significant adjustment for publication selection effects was warranted based on the standard errors clustered by article in the weighted least squares results, but the mean estimated VSL after making the adjustment was to reduce the VSL to $9.6 million, which is in line with estimates used by U.S. government agencies. Using the same sample as in Doucouliagos, Stanley, and Giles (2012) and samples augmenting it with CFOI data, the bias-corrected VSL levels were around $4 million, but there is an additional $3 million to $4 million premium above the amount if the study is based on the CFOI data. Thus, following the same procedures as in the bias-corrected critiques of the VSL, it is not clear that there is a statistically significant bias in the CFOI estimates. Moreover, even if there is a bias, the magnitude of the bias is not sufficiently great to reduce the estimated VSL below the levels currently used in policy analyses.

Absent any significant bias in the set of results published in the literature, there may still be a bias that arises in the selection of the best estimate from a particular study (Viscusi 2018a). Best-set estimates are more affected by publication selection effects than are the all-set estimates from the studies. For example, the choice might be driven by which estimate is most in line with the published literature rather than which equation specification is preferred. After correcting for publication selection effects, for the all-set sample of CFOI estimates the estimated VSL is $11.4 million, but for the best-set estimates the bias-adjusted VSL is $4.4 million in USD 2015. More substantial adjustments were evident for the full sample including studies not based on the CFOI data.

Because of the prominence of U.S. studies in the revealed preference literature for VSL, there is a tendency of international VSL estimates to use the U.S. VSL figures as the anchor for what estimates are reasonable (Viscusi and Masterman 2017a). While this study produced no evidence of statistically significant biases for estimates of the VSL based on the CFOI data, there was evidence of statistically significant biases for studies using other U.S. government data, U.S. non-government data, non-U.S. government data, and non-U.S. non-government data.

Based on the disappointing performance of compensating differential estimates of the VSL outside the U.S., the natural question is to ask is whether stated preference studies can avoid these biases. Applying the same kinds of tests as were used for labor market studies, Masterman and Viscusi (2020) examine whether publication selection effects also bias stated preference estimates of the VSL. Unfortunately, there are large, statistically significant biases that are evident for all different sets of studies that were considered: articles in peer-reviewed journals, other published articles, health risk VSLs, environmental risk VSLs, traffic risk VSLs, non-U.S. upper-income economy estimates, and upper-middle-income economy estimates.

4. Recent Policy Applications

4.1 Possibly Fatal Regulations

Government expenditures and regulatory requirements often protect individual health, but they also impose an opportunity cost on society. Because of the costs of taxes and regulatory impositions, consumers have fewer resources for personal consumption expenditures, including components that affect mortality, such as health care, safer products, and residence in a safer neighborhood. The economic literature has long noted that greater affluence is associated with decreased mortality and that reductions in income lead to increases in mortality rates (Keeney 1990; Graham, Chang, and Evans 1994). For example, mortality rates rise after income shocks, such as during periods of high unemployment. Because of the income-health relationship, costs resulting from government efforts will have an indirect impact on individual health as mortality rates will be adversely affected through the income-health relationship. Although the impact is not necessarily problematic, if the focus of the policy is to enhance individual health, then the indirect effect should be taken into account when assessing the net policy impact on health.

The income-health relationship is quite general, but it has received the greatest policy prominence with respect to assessing health impacts for policies that fail a benefit-cost test, as many U.S. policies formerly did. The VSL plays a direct role in benefit-cost analysis through the monetization of the changes in mortality risk resulting from a policy. If policy design is economically efficient, only policies with benefits exceeding costs will be adopted. In some instances, U.S. statutory requirements direct the agency to promote risk reductions such as improvements in air quality independent of whether they pass a benefit-cost test. However, the calculated costs of policies that the agency wishes to adopt may exceed the benefits. In an effort to impose some fiscal discipline on risk and environmental regulations that have costs exceeding benefits, the U.S. Office of Management and Budget (1992) suggested that a decision by Justice Stephen Williams was pertinent. In that decision, he suggested that policies should be judged based on whether the net impact on health was favorable, taking into account the indirect effect of the income-health relationship, rather than whether the direct health impacts alone reduced health risks. Based on estimates of the income-mortality linkage, the cost-per-life-saved cutoff for a counterproductive impact for that analysis was $23.2 million (USD 2020) per statistical life. A cost imposition of this amount would lead to one expected death based on this approach.

In addition to being a counterintuitive result that suggested that risk and environmental regulations on balance could harm rather than promote individual health, there were two principal economics concerns with this approach to assessing the cost-per-life-saved cutoff. First, the empirical relationship between income and health is two directional. While having more economic resources enables the consumer to purchase a safer product mix, being healthy also enables a person to earn more income. Most studies did not successfully disentangle this relationship, and some were based on aggregate economic statistics rather than statistical analyses that might address these concerns. Second, a $23 million figure at which the cost imposition leads to one statistical death is only just over double the value of the VSL. It is unlikely that many mortality risk reductions that were valued at the VSL would have been desirable in the market contexts in which people were making expenditures to reduce risk. An expenditure of just over $11 million per statistical life would have a direct effect of saving one statistical life but lead to an indirect effect offset of one-half of an expected death. Would the expenditures be desirable if people, in effect, were only doing a bit better than breaking even with respect to whether there would be a net reduction in their risks?

To examine the issue of an informative upper bound on the aggregate cost of saving a life, Viscusi (1994) developed a theoretical model in which the counterproductive cost per life saved value is explicitly linked to the VSL. In the model, he demonstrates that the cost imposition that would lead to the loss of one expected death equals the VSL/(marginal propensity to spend on health). At the time of the article, the marginal propensity to spend on health care was 0.1, so that the cost imposition that would lead to one statistical death based on a current estimate of the VSL of $11 million would be given by 10 x VSL, or $110 million. Thus, if a government policy reduces mortality risks at a cost of $110 million, then on balance more people will die than be saved as a result of the regulatory policy.

There have been subsequent efforts to refine the estimate of the marginal propensity to spend on health, such as including other income-related expenditures that have an adverse effect on health, including smoking and drinking, which lower the cost-per-life-saved cutoff before expenditures become counterproductive (Lutter, Morrall, and Viscusi 1999). The recent update by Broughel and Viscusi (2021) found that the marginal propensity to spend on health was still about 0.1. Using a VSL of $10.3 million based on U.S. Department of Transportation VSL estimates in USD 2019, they concluded that the current midpoint estimate of the cost per life saved cutoff was $108.5 million, or 10.5 times the value of the VSL.

Although calculated benefits of government policies now usually exceed the costs, if the benefits are overstated then there still could be net adverse health impacts. Regardless, the cost-per-life-saved cutoff estimates highlight the mortality loss that accompanies the decrease in available economic resources for households. Application of the cost-per-life saved cutoff analysis also makes it feasible to project the mortality loss associated with government efforts, such as the adverse mortality impact resulting from the reduction in the GDP due to the economic shutdowns during the COVID-19 pandemic (Viscusi 2020, 2021b).

4.2 Extending the Domain of the VSL

For several decades the VSL has been firmly entrenched in the monetization of proposed government regulations. The U.S. Office of Management and Budget routinely concludes that these monetized mortality reduction benefits comprise the largest benefit component across all new government regulations. Despite the widespread adoption of the VSL in regulatory impact analyses the VSL has been underutilized by government agencies as well as the judicial system. Setting a price on mortality risk reduction has broad applicability in many situations, some of which will be noted here and are elaborated on elsewhere (Viscusi 2018b, 2021a). The discussion below provides illustrations of potential uses of the VSL in several different contexts -- policy analyses other than regulatory impact analyses, setting regulatory sanctions for violations that lead to fatalities, and setting damages in the courts.

4.2.1 Policy Analysis: Applications to the Military

Although the VSL has been used in some policy contexts other than when valuing proposed regulations, it has not achieved the same level of acceptance as in the case of regulatory impact analyses. Consider first the case study of protective armor decisions by Kniesner et al (2015). Adding additional protective armor to military vehicles reduces the risk of death, but also increase the weight of the vehicle and imposes costs. The authors considered three different levels of armor -- light, medium, and heavy -- and assessed the marginal costs of increasing the protective capabilities. Which level of armor was optimal depended on the use of the vehicle and the extent to which it would be exposed to dangerous situations. The basic light armor would be appropriate for low-risk administrative support units. Moving to medium armor is more protective and more expensive, with the marginal cost per life saved of $1 million to $2 million. Adopting heavy armor would triple the cost but with no appreciable decrease in risk, given risk assessments based on past experience.

The desirability of medium armor is clear cut for almost all reasonable estimates of the VSL, but the context provides a useful framework for exploring the different possible VSL approaches that one could take. First, a default approach is to use the average economy-wide VSL in the pertinent time period to value military deaths. This is the approach taken in Viscusi (2021), who found that the mortality costs of wars were $114 billion for the Vietnam War and $95 billion for the post-9/11 wars, where $57 billion was for the war in Iraq and $38 billion was for the war in Afghanistan. Using a uniform VSL is consistent with standard government practices and is likely to be less controversial than using an approach the assigns a lower value to military deaths than to non-military mortality risks. A second possible VSL approach is to use age-adjusted estimates of the VSL. Given the inverted-U shape of the VSL trajectory over the life cycle, application of an age adjustment would lead to a reduction in the VSL compared to the average economy-wide value. A third approach to selecting a VSL for military deaths is to use income-based VSL estimates obtained by adjusting the economy-wide VSL using the income elasticity of the VSL. Because the military personnel who are exposed to the risk have below average income levels, income-adjusted VSLs will lead to a lower VSL than the overall average VSL. A fourth approach is to use VSL levels estimated in the specific policy context. As discussed above, Rohlfs (2012) provides estimates of the VSL in the $1.6 to $5.2 million range based on college enrollment decisions to avoid the draft during the Vietnam War and $7.4 to $12.1 million based on military enlistment decisions.

The diversity of approaches to selecting the VSL for the military highlights some of the potential refinements that might arise if there is an effort to tailor the VSL to the particular policy context. As this example indicates, it is possible to use either an average VSL estimate or consider one of several different approaches that are available to incorporate the context-specific heterogeneity of the VSL. Recognition that application of the VSLY rather than the VSL is appropriate for valuing reductions in mortality risks for those with very short life expectancy has gained some acceptance. However, to date there has been no widespread effort to incorporate the heterogeneity of the VSL in policy assessments. (For further discussion see Armey et al. 2021).

4.2.2 Regulatory Sanctions

Government agencies routinely promulgate regulations that are designed to reduce mortality risks. Whether there will be the predicted reductions in mortality risks borne out depends on the enforcement of the regulations. What sanction is appropriate for regulatory policies that are intended to induce firms to undertake the necessary safety investments? The expected penalty and other economic losses associated with violations of the regulatory standard should be sufficient so that the marginal cost-risk tradeoff for the firm is the same as would be generated in a fully informed market through the VSL.

Although the VSL clearly should be pertinent to setting regulatory sanctions, it is not. Most of the risk-related regulatory agencies were established a half century ago when the VSL approach had not been adopted by government agencies even for regulatory analyses. When Congress formulated the legislative mandates for regulatory agencies it included the provision for penalties if there were regulatory violations. However, it also set penalty caps that were not grounded in any economic theory of optimal regulatory enforcement. Although penalty caps have been increased periodically for inflation, they remain quite low such that the maximum penalty for a fatality involving violation of an OSHA safety regulation is currently only about one percent of the U.S. VSL of $11 million discussed above (Viscusi and Cramer 2021).

The role of penalty caps for motor-vehicle safety highlights the extent of the deficiency in the economic incentives generated by penalties. General Motors marketed several lines of vehicles that had a defective ignition switch that led to numerous crashes. Although the company became aware of the defect, remedying the problem would impose costs. As a result, the company chose to continue to market a risky product. The crashes resulting from the defective ignition switch resulted in 124 deaths, 275 injuries, and substantial property damage to the vehicles. In 2015 the National Highway Traffic Safety Administration (NHTSA) levied the largest penalty that the statute permitted for any single defect, which at the time was $35 million. Excluding the losses associated with the nonfatal injuries and property damage, the penalty level per fatality was only $282,000, or 3% of the value of one statistical life.

The NHTSA experience is not unique, as very low statutory caps on damages are standard (Viscusi 2018b, 2021a). The Occupational Safety and Health Administration generally inspects firms following worker fatalities. If regulatory violations led to the fatality, it might assign penalties for these violations. In fiscal year 2018 the total penalty that was imposed after fatality investigations was $7,761 for federal inspections and $2,700 for state inspections. The Food and Drug Administration's statutory guidance similarly incorporates caps that limit penalties. In 2017 the caps were $76,352 for any individual introducing adulterated food into interstate commerce and a combined limit of $763,515 for any series of violations in a single proceeding. The caps are particularly low given that food products are mass marketed so that the harms may affect a large number of consumers, such as the 33 deaths from contaminated cantaloupe from a Colorado farm, multiple fatalities from Sara Lee hot dogs contaminated with listeria, and nine deaths from a brand of contaminated peanuts.

The result of the mismatch between the magnitude of the regulatory sanctions and the harms that they are intended to prevent is that regulatory policies are largely aspirational and may fail to deliver the proposed mortality risk reductions. Incorporation of the VSL in the construction of the guidelines for penalty levels and, in particular, in the setting of the penalty caps, could promote more efficient levels of deterrence.

4.2.3 VSL in the Courts

The VSL has one current use in the courts as well as two potential uses (Viscusi 2018b). The current use of the VSL is in setting the value of compensatory damages in wrongful death cases. The use of the VSL in setting compensatory damages has attracted the attention of plaintiff attorneys since the VSL often exceeds the present value of lost earnings by an order of magnitude, creating the potential for substantially larger damages awards. An approach involving the VSL, which has come to be known as hedonic damages, has been espoused in the literature by Posner and Sunstein (2005) and by Polinsky and Shavell (1998). From an economic standpoint, routine use of the VSL for compensatory damages may provide efficient levels of deterrence but will provide excessive levels of insurance. Purchasers of potentially dangerous products will be paying for the VSL insurance payoff *ex ante* through higher product prices. Few people would choose to buy life insurance that provided for a payout in the range of the VSL. Most jurisdictions have not accepted the use of the VSL in setting damages after fatal injuries.

Two alternative uses of the VSL in legal contexts are more directly linked to economic theory. First, the VSL provides the yardstick for assessing whether the firm has made a sufficient investment in product safety. Suppose that an auto company could install a safety device for which the costs and expected mortality reduction are known. Then, as in the military armor choice discussed above, if the cost per expected life saved is less than the VSL and the company chose not to adopt the safety device, then the company would be guilty of negligence. If the cost per expected life saved exceeded the VSL, then not adopting the safety measure would be efficient and the company should not be found liable. Thus, the VSL can be used in setting the reference point for determining liability. Second, the VSL is the optimal deterrence amount so that in some circumstances it does have a legitimate role in setting damages. In situations in which creating safety incentives is of concern, which is typically in cases in which there are punitive damages, setting the total award level equal to the VSL will provide efficient levels of deterrence. The sum of the compensatory damages and punitive damages should then equal the VSL.

4.2.4 The COVID Pandemic of 2020-

A most important application of VSL and VSI has been to examine the cost of the pandemic to date and by extension the benefit of interdicting the future spread to COVID and its emerging variants. Using a VSL of about $11 million for the U.S., an income elasticity of unity to convert it to values for other countries, and adjustments for the facts that COVID is a more serious health issue for the elderly and that death is not a marginal change in health, Viscusi (2020) calculated the world-wide economic cost of the over 500,000 pandemic related deaths to have reached $3.5 trillion by the middle of 2020, with the U.S. accounting for about 41% of the mortality costs.

The morbidity effects of the spread of COVID are more difficult to infer, particularly as one need include the so-called dread effects from not only the way the disease manifests itself via difficulty breathing but also from the patients' worry that the situation will worsen to the point of death. Although less serious medically than death the morbidity effects are more widespread in that non-fatal cases have been 30 times greater overall with twice as many hospitalizations for non-fatal COVID than the number of COVID-related deaths (Kniesner and Sullivan 2020). Using a variety of estimates for the cost of non-fatal covid cases in the United States that include past estimates of controlling a similar medical situation such as asthma and the values that U.S. government agencies place on the cost of non-fatal health problems by severity with adjustments for dread, age and income, increases the cost of the COVID pandemic by an additional 10% to 100% (Viscusi 2020; Kniesner and Sullivan 2020). Finally, we note that there is still much highly interesting and important research emerging involving how to use VSL estimates to calculate the benefits of interdicting an pandemic (Viscusi 2010, 2020; Hammitt 2020) and the relative cost effectiveness of expensive widespread social distancing versus a cheaper alternative that is the widespread rapid testing of individuals for the presence of infection with a more limited social distancing of only those who test as infected (Thunström, et al. 2020; Gabler, et al. 2021).

5. Conclusion and a Brief Look Into the Future

It is important to emphasize the dual objectives we have pursued here because of the enduring many uses of estimates of the value of a statistical life or injury. Not only does VSL/VSI capture an empirically robust and enduring compensating wage differentials for job characteristics, but it also continues to have wide and growing applicability in policy evaluation and formulation. After emphasizing how the value of a statistical life resides inside an estimable model of hedonic labor market equilibrium, we showed how the VSL concept has much flexibility should the researcher be interested in morbidity versus mortality, lost life years, small versus large changes in the probability of death, and life-cycle effects where VSL as related to age are concerned. Recent examples that we have fleshed out include numerous applications of VSL as an important component of the benefit of policies to extend life or to improve the health-related quality of life. The advantage of labor market estimates is that one is not left to deal with hypothetical decisions but rather decisions where actual health and safety decisions are involved for an individual. Labor market estimates based on the CFOI are also less subject to publication selection biases than stated preference estimates.

Because of the large amount of data on interpersonal demographic and situational heterogeneity the VSL/VSI concepts can be targeted to policies affecting important demographic (including age) and industry (including military) subpopulations. We also explicated international comparisons of VSL via the estimated income elasticity of VSL. It has been important to emphasize subtle applications of VSL to cost-benefit calculations of regulations to reduce mortality, which at some point can be not only cost ineffective but also socially welfare reducing because they reduce personal health and safety expenditures. We have summarized the important contributions of VSL calculations to understanding the cost of the COVID pandemic now ongoing.

Finally, emerging policy issues that will involve the VSL and VSI on the benefit side of any welfare calculation include environmental policies such as carbon taxation or emissions regulations, the possibly expanding use of potentially COVID-reducing nudges which may occur inside of government (Sunstein 2021, Thaler and Sunstein 2021), and planned introduction of distributional issues in benefit-cost analysis of regulatory policies more generally (U.S. Office of Management and Budget 2021).

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