The Value of a Statistical Life

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Summary and Keywords

The value of a statistical life (VSL) is the local tradeoff rate between fatality risk and money. When the tradeoff values are derived from choices in market contexts the VSL serves as both a measure of the population's willingness to pay for risk reduction and the marginal cost of enhancing safety. Given its fundamental economic role, policy analysts have adopted the VSL as the economically correct measure of the benefit individuals receive from enhancements to their health and safety. Estimates of the VSL for the United States are around $10 million ($2017), and estimates for other countries are generally lower given the positive income elasticity of the VSL. Because of the prominence of mortality risk reductions as the justification for government policies the VSL is a crucial component of the benefit-cost analyses that are part of the regulatory process in the United States and other countries. The VSL is also foundationally related to the concepts of value of a statistical life year (VSLY) and value of a statistical injury (VSI), which also permeate the labor and health economics literatures. Thus, the same types of valuation approaches can be used to monetize non-fatal injuries and mortality risks that pose very small effects on life expectancy. In addition to formalizing the concept and measurement of the VSL and presenting representative estimates for the United States and other countries our *Encyclopedia* selection addresses the most important questions concerning the nuances that are of interest to researchers and policymakers.

Keywords: value of a statistical life, VSL, CFOI, hedonic equilibrium, value of a statistical life year, VSLY, morbidity risk, mortality risk, benefit transfer, willingness to pay

Why Monetize Risks to Life?

The principal focus of health, safety, and environmental regulations and many public health-related policies is to enhance individual health, where the most consequential impacts often pertain to reductions in mortality risks. Policymakers seeking to assess society's willingness to pay for expected health improvements need some measure of the associated benefit values to monetize the risk reductions and to facilitate comparison of benefits and costs. Standard economic practices for valuing mortality risks historically focused on the human capital approach in which the value of an expected fatality was equated with the present value of the loss in income and medical costs associated with the death. The shift to focusing on risk-money tradeoff rates as being the correct economic approach for conceptualizing the valuation of risks of death stemmed from the research by Schelling (1968), though he was skeptical of the ability to estimate the value using either survey evidence or market data. It was not until the 1980s that subsequent empirical research led to reliable estimates of the VSL, which has been used by U.S. government agencies to value changes in mortality risks.

Since then the VSL has become the most important economic parameter for the evaluation of U.S. government regulations, and it has been adopted internationally as well (Narain & Sall, 2016; OECD, 2012; Sunstein, 2014; Viscusi, 2018b). The evaluation of the mortality risk benefits of proposed new regulations is the largest component of all new regulatory benefits, with regulations by the U.S. Environmental Protection Agency and the U.S. Department of Transportation accounting for the largest share of the benefits of regulations targeting mortality risk reduction (U.S. Office of Management and Budget, 2015).

The following discussion reviews the theoretical underpinnings of the VSL approach and examines the research to derive VSL estimates. There have been two principal avenues of empirical research: revealed preference evidence, and stated preference evidence. The revealed preferences studies have chiefly relied on labor market estimates that have been facilitated by the availability of extensive and accurate occupational risk and employment data, but there also have been numerous product market studies linking product prices to risk levels. Stated preference studies are based on hypothetical decisions rather than actual behavior but can be particularly useful for studying risk outcomes for which market data are not informative and for countries in which the risk and employment data are not well suited for obtaining revealed preference evidence. In addition to reviewing evidence on the VSL from the multiple empirical approaches and data sources, we also present a succinct review of government practices using the VSL in the United States and other countries.

Basic Theory

A fundamental aspect of product and labor markets emerging formally in the theoretical and empirical economic literatures involves the attributes of the goods and services being exchanged. As emphasized by Sherwin Rosen in his influential research, quality matters to price not just quantity (Greenstone, 2017). Better goods and services, and workplace settings cost more to create, are more highly valued by their consumers, and in turn have higher prices and lower wages.

For our purposes we focus on the situation where more dangerous or hazardous jobs are less desirable to workers and require higher wages, everything else the same. Similarly, safer job settings are more costly for firms to create, ceteris paribus, so that firms will have to pay lower wages in a zero economic profit competitive environment, and some workers will accept such lower wages as an implicit payment for better, safer jobs. A similar process is at work in product markets where safer, more reliable, products cost more to produce and are more highly valued by consumers. What economists call the hedonic equilibrium locus describes the collection of price and quality combinations that have the quantity supplied equal the quantity demanded at every different quality attribute.

The hedonic equilibrium wage locus is the collection of wage and health risk combinations, each of which has the number of workers willing to take the jobs equal the number of jobs at the specific wage-safety situation. (Kniesner and Leeth [1988] present the nuts and bolts of the hedonic labor market equilibrium process with numerical examples.) Later we will discuss estimates of how product markets also reveal the value of safety. For now, we need a simple description of hedonic equilibrium in the workplace.

Algebraically, labor market hedonic equilibrium is described most simply by the equation $w = w(p)$, where w is the wage and p is the probability of a fatal injury or fatal health hazard exposure at work with the property that $w' = dw/dp > 0$, so that less safe jobs must pay a higher wage, everything else the same. One must be careful to remember that the proper comparison here is within an industry and occupation across workplaces. Of course, corporate executives have more highly paid and have safer jobs than production workers. What we are focusing on is a situation such that test pilots are more highly paid than commercial airline pilots because of the much greater risk of death. Similarly, janitors who clean out the insides of a nuclear reactor are paid much more (16 times more) than janitors who clean commercial office buildings.

The value of a statistical life (VSL) flows straight from the numerical value of the slope of the hedonic wage or product price locus. Suppose that p is the probability of an accidental death at work and is measured by the number of accidental worker deaths per 10,000 workers. Suppose further that the estimated hedonic locus reveals that the typical worker in the labor market of interest, say manufacturing, needs to be paid \$1,000 more per year to accept a job where there is one more death per 10,000 workers. This means that a group of 10,000 workers would collect \$10,000,000 more as a group if one more member of their group were to be killed in the next year. Note that workers do not know who will be fatally injured but rather that there will be an additional (statistical) death among them. Economists call the \$10,000,000 of additional wage payments by employers the value of a statistical life. It is also the amount that the same group of workers would be willing to pay via wage reductions to have safer jobs where one fewer of their group would be fatally injured or ill. In that sense the VSL measures the willingness of workers to implicitly pay for safer workplaces and can be used to calculate the benefits of life-saving projects by private sector managers and government policymakers.

The other important result in play in hedonic labor markets is the sorting of workers and firms in a set of economic "marriages" in the labor market. In addition, the hedonic locus is generally nonlinear so that $w" = \frac{d^2w}{dp^2} \neq 0.$ Firms who have the lowest marginal cost of workplace safety hire the workers who value safety the most, and the firms where it is most difficult (costly) to improve safety hire employees who are the most willing to take a risk concerning their personal health and safety at work. The sorting of workers across employers by safety concerns and costs is economically efficient. This also means that the VSL will depend on the particular level of risk/safety in the situation under consideration. Later we consider equity issues surrounding personal health and safety and the VSL. Now we turn our attention to estimating the VSL.

Estimating the VSL

The canonical estimating equation for the VSL as revealed by labor market survey data on workers' wages and fatal injury risk is a regression that controls for other relevant personal characteristics affecting wages. In addition, there is a long tradition in labor economics that uses the semi-logarithmic form based on human capital theoretical concerns and econometric specification checking (Heckman, Lochner, & Todd, 2008; Heckman & Polachek, 1974). The multivariate regression approach leads to the workhorse regression equation in the literature that is typically referred to as the Mincer equation in light of the contributions of Jacob Mincer that is $\ln(w_{i,j,k}) = \alpha + \beta p_{i,j,k} + X_{i,j,k}\Gamma + u_{i,j,k}$, where for worker i in industry j and occupation k the dependent variable is the natural logarithm of the real wage, p is the work-related fatality rate, and X is a vector with both demographic control variables (such as age and education) and other job characteristic variables (such as non-fatal injury risk, workers' compensation insurance coverage, and industry and occupation indicators) with associated coefficient vector Γ. Finally, $u_{i,j,k}$ is an error term whose stochastic properties are reflected in regression coefficients' estimated standard errors.

In the typical semi-log wage equation above the estimated coefficients are so-called rates of return or the proportionate change in the wage per one unit change in the independent variable of interest, which means that $\widehat{\beta}$ estimates $(\frac{\partial w}{\partial p})(\frac{1}{w})$. So, in the case of the typical U.S. fatality risk measure of deaths per 100,000 workers, a wage rate that is average hourly earnings, and a typical work year that is h hours, the value of a statistical life is calculated as VSL = $(\widehat{\beta} \times w) \times h \times 100,000$. It is common to compute the average value of the VSL using $w = \overline{w}$ and h = 2000, the typical work year, or $h = \overline{h}$.

It is important to note that the econometric research on the VSL using the regression approach just summarized has dealt with many econometric complexities and nuances such as latent individual heterogeneity and possible measurement errors in fatality risk so that the empirical econometric literature using revealed preference-type data is vast (Kniesner & Ziliak, 2015). Included in the literature's research concerns and what to do about them are measurement errors in and worker misperceptions or endogeneity of fatal or non-fatal injury risks, possible heterogeneous values for α and β, and dynamics of state dependence in wages. Using the formula for the VSL just presented the mean VSL for U.S. men is about $7 million to $8 million in $2001 (Kniesner, Viscusi, Woock, & Ziliak, 2012). Although other specifications may lead to different VSL estimates, it is noteworthy that even after these extensive controls the general range of the VSL is similar to the levels frequently used in U.S. policy contexts.

Representative Estimates

Although the level of VSL estimates depends on the sample, the risk measure, and the equation specification, the general order of magnitude of the estimates has remained quite stable. The widely cited review by Viscusi and Aldy (2003) focused on what the authors generally regarded as the best estimates of the VSL in their research. The "best estimates" would correspond to the one equation (specification) that in the authors' view constituted the most meaningful estimate of the VSL among the possibly many estimates presented in the article. Using the values from a series of studies, Viscusi and Aldy found that the median VSL was $7 million ($2000). Given the timing of their meta-analysis, their review did not include the recent VSL estimates based on the Census of Fatal Occupational Injuries (CFOI) data, which involves less measurement error than previous fatality rate measures because it is a comprehensive census of all work-related fatalities, which have also been verified using multiple sources.

The article by Viscusi (2018a) includes VSL estimates based on the CFOI data and is also more comprehensive in that it includes an analysis of the single best estimates from each study and also an analysis of every reported VSL estimate in the studies. Including all estimates alleviates the selection bias that may arise from selection of the "best estimate," thus avoiding the bias arising if the review process or the preferences of the authors create a tendency to choose estimates consistent with the existing literature as the focal estimate. The sample included 1,025 VSL estimates drawn from 68 publications, as the best estimates constituted just under 7% of all VSL estimates reported in the 68 studies. The all-set mean VSL is $12.0 million and the best-set sample mean is $12.2 million, where all estimates are in $2015. The median values are somewhat lower—$9.7 million for the all-set sample and $10.1 million for the best-set sample.

Viscusi (2018a) also found more substantial differences in the VSL estimates across countries. The estimates for the U.S. studies were somewhat higher than for other countries. The all-set U.S. median was $10.3 million for U.S. studies and $7.1 million for non-U.S. studies, and for the best-set sample the U.S. median was $10.2 million and the non-U.S. median was $7.9 million. The level of the VSL estimates in international studies also varies with the fatality rate data set used. For studies using fatality data generated by government agencies, the VSL estimates from countries other than the United States have a mean value of $13.8 million and a median value of $6.9 million, whereas the non-U.S. studies based on non-governmental fatality rate data have a mean VSL of $8.7 million and a median VSL of $9.8 million ($2015) (Viscusi & Masterman, 2017a).

The most reliable U.S. estimates are those based on the CFOI data, which is the fatality risk variable with the least measurement error. Based on the estimates reported in Viscusi (2018a), the mean estimate based on the CFOI-based studies is $13.1 million, and the median estimate in the literature is $11.1 million ($2015). Although CFOI-based estimates are similar to those in some other studies, they are less subject to publication selection biases. Whereas other U.S. and international estimates are substantially reduced by adjustments for publication selection biases, the CFOI-based studies are not. The bias-adjusted CFOI estimates are just under $10 million, which is the focal VSL estimated used in Viscusi (2018b).

Heterogeneity of the VSL

As with the preferences for other economic goods, there is substantial heterogeneity in the VSL both within and across countries. Some of the differences are grounded in economic theory. Most obviously, the VSL should increase with income if reducing mortality risks is a normal economic good, and the VSL is likely to vary with age both because the amount of remaining life expectancy declines with age and because economic resources and family obligations vary with age. The various influences on the VSL are often confounded, as individual economic resources also have a strong age relationship. There are other aspects of the heterogeneity for the VSL that have been of research interest as well, such as variations in the VSL by gender, race, immigrant status, occupational type, and union membership. International cultural differences also may be influential, but there has been little research on the cultural issue. Previous meta-analyses (Blomquist, 2004; Kochi, Hubbell, & Kramer, 2006; Lindhjem, Navrud, Braathen, & Biausque, 2011; Mrozek & Taylor, 2002; Viscusi, 1993; Viscusi & Aldy, 2003) review both the VSL, and much of the evidence on the heterogeneity of the VSL. The discussion here focuses on the role of income and age.

There is a substantial literature documenting the positive income elasticity of the VSL using labor market data. The policy role of income elasticities is important both from the standpoint of updating agencies' VSL estimates over time to reflect increases in societal income levels (U.S. Department of Transportation, 2016) and to transfer VSL benefit values across countries with different income levels (Hammitt & Robinson, 2011).

One procedure for estimating the income elasticity of the VSL is to study the VSL estimates in a meta-analysis of VSL studies. The meta-analysis by Viscusi and Aldy (2003) estimated a series of equation specifications from four previous meta-analyses of labor market VLS estimates using a large, consistent sample of studies, estimating an income elasticity in the range 0.5 to 0.6. Other model formulations yielded elasticities from 0.46 to 0.60. The meta-analysis by Viscusi and Masterman (2017b) estimated a U.S. income elasticity of 0.55 and an income elasticity for non-U.S. countries of 1.1. Robinson, Hammitt, and O'Keefe (2019) explore income elasticity estimates for low- and middle-income countries. Differences in income levels account for much of the international disparity, as the income elasticity is greater at lower income levels. The estimated income elasticity ranged from 2.58 at the 5th percentile to 0.35 at the 95th percentile of the income distribution.

Rather than estimate the income elasticity based on VSL estimates of different studies, a second approach to examine the income elasticity estimates across a large set of previous meta-analyses of the income elasticity of the VSL. A meta-meta-regression of the income elasticities from previous meta-analyses found that the most precisely estimated elasticities and the bias-corrected elasticities were in the narrow band from 0.61 to 0.62 (Doucouliagos, Stanley, & Viscusi, 2014).

A third labor market approach is to estimate the income elasticity across the wage distribution using quantile regression models (Kniesner, Viscusi, & Ziliak, 2010). The average estimated income elasticity was 1.44, with a range from 2.2 at the 10th percentile to 1.2 at the 75th percentile, reflecting a pattern similar to that found in the subsequent study by Viscusi and Masterman (2017B).

A fourth labor market approach is to estimate the income elasticity of the VSL based on long-term historical trends in income and the VSL. One would expect the estimated VSL to be greater in more recent employment periods because of increases in societal income levels. One caveat is that fatality risk data quality and procedures for constructing the data also may have changed over time. Using labor market approximations from 1940 to 1980, Costa and Kahn (2004) estimate an income elasticity of the VSL of 1.5 to 1.7.

The income elasticity estimates from stated preference studies are also positive and are in a similar range. Based on a large-scale meta-analysis of stated preference studies the average income elasticity is 0.7 to 0.9 (Lindhjem et al., 2011). The stated preference evidence is instructive in that it reflects findings throughout the world. To the extent that the income elasticity of the VSL is a decreasing function of per capita gross national income, one would expect that inclusion of stated preference evidence from lower income nations would lead to a higher average estimated income elasticity than the average estimates found in U.S. studies.

The role of age variations in the VSL is of theoretical interest and also may be pertinent to policy evaluations in which particular age groups are affected disproportionately by the policy effort. The role of age adjustments gained particular notoriety with respect to the debate over the U.S. Environmental Protection Agency's (2002, 2003) benefit assessment for the Clear Skies initiative. That application used evidence from a U.K. stated preference study (Jones-Lee, Hammerton, & Philips, 1985) to reduce the VSL for those over age 65 by 37%, leading to a public outcry from senior citizen groups and an abandonment of age adjustments. Subsequently, U.S. government agencies do not use age-adjusted estimates of the VSL.

Evidence on the relationship between age and the VSL varies with respect to the study method. Evidence from stated preference studies has been inconsistent (Krupnick, 2007), with some studies showing a flat relationship of the VSL with age, and others showing a declining age-VSL relationship, as in Jones-Lee, Hammerton, and Philips (1985).

Although early labor market evidence on the age–VSL linkage showed a declining VSL–age relationship, after the advent of age-specific occupational fatality data it became possible to obtain more meaningful revealed preference evidence. Labor market studies of the VSL–age relationship have consistently shown an inverted U-shaped pattern for studies using age-specific mortality data. The inverted U-shape pattern is consistent with economic models in which there are limitations in capital markets and insurance markets that prevent a person from drawing on discounted expected lifetime wealth beginning at birth. In the absence of such limitations, models often suggest a steadily declining VSL with age (Shepard & Zeckhauser, 1984).

Consider, for example, the results in Aldy and Viscusi (2008). The estimated VSL rises with age, peaking at age 46. Although the VSL subsequently declines, it does not plummet, as the VSL for workers age 62 remains 50% greater than the VSL of those age 18. The role of income effects is more influential than the shortened life expectancy at risk. The age-related pattern of VSL that rises and then falls over the life cycle follows a trajectory that is familiar to labor economists, as it also tracks the life-cycle pattern of consumption (Kniesner, Viscusi, & Ziliak, 2006).

How Markets May Be More Complex

The standard hedonic wage model assumes that workers face a common labor market offer curve. However, there may be labor market segmentation in which some workers face wage–risk curves that are flatter than the curves faced by other workers so that the marginal wage premium for increases in risk is lower for those facing flatter offer curves. The observation that some worker groups receive lower total wage compensation for greater risk levels would be consistent with such labor market segmentation.

Based on a model allowing segmentation, Viscusi and Hersch (2001) found that smokers received a lower implicit value of compensation for job injuries than nonsmokers even though they faced greater occupational risks. Similar results pertain to racial differences in estimated VSL levels. A particularly striking result is that immigrant workers face fatality risks about 1.5 times as great as non-immigrant Americans, but they receive less wage compensation for the risks and, in the case of Mexican immigrants who are not fluent in English, there is no statistically significant compensating differential for the fatality risks (Hersch & Viscusi, 2010).

Economists have also begun to introduce practical psychological issues into their models, both theoretical and empirical, which is the emerging field of behavioral economics (for a comprehensive treatment of the field, see Dhami, 2016). We now delve into how two core behavioral economic concerns affect VSL conceptually and empirically. The two we consider are worker misperceptions of fatal injury risk at work, and loss aversion whereby workers may evaluate an increase in health risk differently from an equivalent decrease in health risk.

The working assumption in the econometric literature is that subjective beliefs of workers and employers concerning workplace hazards are well represented by objective measures of risk in the regression analysis. Workers and firms can easily take into account available information concerning employer accident records in their risk beliefs. In the econometric models the risk measures, such as from the highly regarded and widely used CFOI, are intended to represent workers 'subjective beliefs of health and safety hazards at work. Research has shown that there is a strong correlation between workers' stated risk beliefs and governmentally collected publicly available injury rates (Viscusi & Aldy, 2003). Research results are that VSL is little affected by including subjective risk beliefs along with actual job risks (Viscusi, 1979a) and that workers can adjust their actual risk levels to possibly mistaken risk levels by quitting and seeking another employer once they determine the true level of risk on the job (Viscusi, 1979a, 1979b). The conclusion to be drawn here is that incorporating risk misperceptions into hedonic wage equations has had little effect on estimated VSL.

Another departure from standard hedonic wage models stems from the behavioral economic topic of loss aversion where marginal tradeoff rates may be different for increases and decreases in risk. Loss aversion implies a possible disparity between willingness to pay (WTP) values for risk decreases and willingness to accept (WTA) values for risk increases, which are equal in the standard hedonic model. Most studies of WTA–WTP disparity have been based on stated preference evidence and, in some instances, on experiments, usually with small stakes. Meta-analyses of stated preference studies have found a mean WTA/WTP ratio of 7.2 (Horowitz & McConnell, 2002) and a geometric mean ratio of 3.3 (Tuncel & Hammitt, 2014). If labor market estimates were subject to a similar disparity, it may be appropriate to adjust VSL values to account for potential biases. However, the estimates for job changers in Kniesner, Viscusi, and Ziliak (2014) found that the VSL estimates implied by the WTP values reflected in workers taking safer jobs for less pay were not statistically different from the WTA values for workers who were paid more to accept jobs with greater risk levels than their starting level.

Product Market Evidence and the VSL Goes to War

Housing prices are particularly amenable to inferring the VSL. Houses in more desirable or personally safer areas will sell for more. More desirable attributes here would include lower pollution or other health hazards such that the likelihood of earlier death is lower, all else the same. The resulting higher house price can be used to infer VSL. Gayer, Hamilton, and Viscusi (2000) estimate a house price equation that reveals an implicit price of cancer avoidance by buyers. In particular, they use risk and individual house price data from an area surrounding a Superfund Hazard site near Grand Rapids, Michigan, to estimate the connection between house prices and environmentally based cancer risk. In the period following the EPA's release of the health hazard information, a 1.81/1,000,000 reduction in cancer risk (the mean level in their data) raised the average house price there by about $34 ($2017 based on Box-Cox estimates). Taking into account the average number of household members of about 2.6, the per person value of reducing one cancer is about $7.2 million ($2017), which is the implicit VSL.

Economists have studied other product purchases to add to the evidence on VSL (Viscusi & Aldy, 2003). When people buy products that increase safety directly such as bike helmets (Byl, 2013) or smoke detectors Garbacz (1989), one can divide the cost of the product by the lower likelihood of death from its use if the safety benefit is the principal product attribute motivating the purchase. The time and effort costs of using safety devices such as seatbelts can also be used to impute the VSL (Blomquist, 1979). Using data on car prices we can infer VSL from the marginal willingness to pay for seatbelts or air bags and even get a distribution of VSLs. Rohlfs, Sullivan, and Kniesner (2015) found the median willingness to pay for automobile air bags was in the range $9 million to $11 million ($2010). Yet another situation is where more safety does not have a monetary outlay with it, such as driving slower or other examples of self-protection (Blomquist, 2004). In such cases one can infer a VSL by associating the safety effects with estimates of the monetary cost of the extra travel time involved to drive slower.

The VSL has recently been inferred in the context of military personnel decisions. Rohlfs, Sullivan, and Kniesner (2015) use data from all European theater army ground battles in World War II to study the implicit value commanders placed on infantry men's lives by their allocation of tanks, which saved infantry lives. Their estimates ranged from $0 to $6 million, which brackets estimates of the VSL in the private sector of just under $1 million in the United States during the 1940s in $1990 (Costa & Kahn, 2004).

Finally, Rohlfs (2012) imputed VSL from two tactics used by young men during the Vietnam War years (1966–1975) to avoid being drafted. One could avoid the draft by enrolling in college or enlisting in the military voluntarily. Those who volunteered could avoid the uncertainty of having their lives disrupted and put at greater risk because they could choose their service branch, get specialty training, and possibly enter the military as officers. Most important for our purpose here is that enlisting improved a soldier's chance of surviving. Over the course of the entire Vietnam War the fatality rates of volunteers and officers were significantly less than draftees' fatality rates. What Rohlfs did was then to examine the higher military pay enlistees required when there was no draft compared to the (lower) pay needed to be willing to enlist when there was a draft. The difference for the marginal volunteer he found was $117,000. If the cost of being drafted was the greater probability of being killed, then the VSL is approximated by the pay difference for enlistees divided by the fatality risk difference which is in the range $7.4 million to $12.1 million for draft age U.S. men ($2009).

Stated Preference Methods

Most policy analyses in the United States favor primary reliance on revealed preference evidence in that the estimates reflect actual tradeoffs individuals make involving risks. The U.S. Department of Transportation (2016) relies only on labor market estimates of the VSL based on the CFOI occupational fatality data, though the U.S. Environmental Protection Agency (2016) supplements the revealed preference-based estimates with findings from stated preference studies. The Organisation for Economic Co-operation and Development (OECD, 2012) relies on stated preference studies as does the United Kingdom. There are many situations in which revealed preference evidence may not be directly pertinent or where it is desirable to consider both stated preference studies and revealed preference studies. For example, the fatality risk data and employment data in other countries may not be as reliable as data from the United States. Although one alternative is to transfer the U.S. VSL estimates to other countries by applying income elasticity adjustments to the U.S. estimates, another possible approach is to obtain country-specific stated preference estimates of the VSL. Doing so potentially can incorporate the influence of differences in culture, life expectancy, and additional factors besides income differences that may affect the VSL. Another role for stated preference studies is to obtain VSL estimates for risks of death, such as cancer, that may be valued differently than the traumatic risks that are the focus of VSL studies based on occupational hazards or motor-vehicle risks.

We now examine how such stated preference studies are structured and the criteria for assessing their validity. In particular, we examine the critical components of a stated preference study for estimating the VSL, including the sample composition, a description of the health outcome, the starting risk level, the change in the risk, the mechanism by which the risk is altered, the payment mechanism, and the nature of the tradeoff elicitation approach. Many of the concerns hark back to the debate over the use of contingent valuation techniques to value the damages associated with the Exxon Valdez oil spill and the research effort that it spawned (Arrow et al., 1993).

The focus of a stated preference VSL study is usually to elicit estimates of the VSL that will be pertinent for policy analyses. Obtaining information on the preferences of a student sample or other samples that are unrepresentative of the population are unlikely to be instructive as the overall task is to obtain an assessment of the affected population's willingness to pay for the mortality risk reduction. There may be substantial differences in sample composition based on the survey mode, such as phone surveys, web-based surveys, mail surveys, and door-to-door surveys. Care need to be exercised in obtaining a sufficiently representative sample that corresponds to the preferences of the population of policy interest.

The health outcome in a VSL study necessarily involves a mortality risk, but the risk events can differ. There may be a latency period between the risk exposure and the health outcome. There also may be unusual morbidity effects associated with the health outcome, as occurs with prolonged illnesses and painful treatment periods before death. It is likely that the consequences of traumatic injuries such as being killed in a car crash are reasonably well known. However, if the survey is intended to elicit valuations of illnesses such as emphysema or heart disease, characterizing the symptoms of the illness is essential for people to understand what good they are valuing. Similarly, it is not sufficient to note that the cause of the death is cancer, as there are many different types of cancer with different morbidity effects. In the absence of specifying the health outcome, respondents may imagine characteristics of the illness that are not correct.

After specifying the risk outcome of interest, the survey generally indicates an initial starting risk value, such as the risk of death from air pollution. This information involves probabilities that may not be well understood by simply stating their magnitude, such as 1/1,000 or 0.001. Researchers have used a variety of approaches to communicate risk probabilities such as risk ladders that provide risk levels for a variety of common hazards (the annual risk of being killed in an car accident, for example) or life expectancies (the probability of living to 100, for example). A frequently used approach is to present respondents with a grid with 1,000 squares, indicating on the grid the baseline risk by coloring the pertinent number of squares. Visual aids may also present the information in terms of a concrete population denominator such as the number of deaths for the population in the state. Conveying probabilities of small risks such as the 1/25,000 average worker fatality risk is challenging because, unlike workers who confront the risks daily, survey risks may be more of an abstraction.

Providing risk information in a survey does not ensure that it is credible and will be the basis of respondents' expressed preferences. Stated probabilities in the survey may not correspond to how respondents perceive the stated probability. If the actual baseline risk is 1/1,000 and the survey states that the risk is 50/1,000, the respondent may not take the stated risk amount at face value but may instead incorporate their prior beliefs in assessing the magnitude of the risk. A well-established finding with respect to mortality risk beliefs is that when people are asked to assess the overall risks to the population, as in Lichtenstein, Slovic, Fischhoff, Layman, and Combs (1978), their assessments are strongly influenced by personal circumstances such as the mortality risk for their age group (Benjamin & Dougan, 1997; Viscusi, Hakes, & Carlin, 1997). Similar kinds of adjustments may affect the baseline risk level as it is perceived by the respondent.

For studies eliciting the willingness to pay, or in some cases the willingness to accept, for a risk change the next component is to specify the change in the risk and the mechanism by which the risk has been changed. If the risk has been conveyed using a grid, indicating the number of squares corresponding to the risk change can convey the magnitude of the risk change. For respondents to believe the risk change it is also desirable to have a credible mechanism that achieves the risk reduction, such as effective air pollution regulations. If respondents do not view the hypothetical survey risks as posing a risk to them or if they do not believe that the risk change will occur, then the VSL estimates will understate the respondent's actual preferences.

The structure of the survey will determine how tradeoffs are elicited. For a risk-money tradeoff survey the task is to elicit how much people are willing to pay for the associated risk reduction. The payment mechanism, such as increased taxes or higher product prices, must be credible. Current stated preference studies are less likely to use open-ended contingent valuation questions or payment cards, indicating a roster of potential valuation amounts, although there are recent exceptions such as the payment card study by Hoffmann, Krupnick, and Qin (2017). Approaches such as dichotomous choices or conjoint analysis have become more common. Consider the dichotomous choice survey valuations for a life-extending product in Krupnick et al. (2002). The survey asks respondents if they are willing to pay a specified amount for a product's risk reduction. Although respondents indicating "yes" were also asked if they would make the purchase at higher specified bid levels, the researchers focused on the tradeoffs implied by the initial responses to minimize order effects. For those indicating "no" to the initial bid, the survey inquired whether the respondent would be willing to pay anything at all for the safety improvement so as to identify zero valuations.

An alternative approach is to use a risk–risk tradeoff approach developed by Viscusi, Magat, and Huber (1991) and used in a series of studies by the authors as well as others such as McDonald, Chilton, Jones-Lee, and Metcalf (2016). For example, suppose that the government is considering a policy choice between transportation regulations that prevent 2,000 expected motor-vehicle deaths and air pollution regulations that would prevent 1,600 expected cases of cancer. Respondents thus would be comparing two different risks rather than risk and money, so that an estimate of the monetary VSL for the traumatic risk could be used as a bridge to establish the VSL for cancer. The survey approach could introduce such present pairwise comparisons and estimate the tradeoff rate across respondents based on the ratio of the two health outcome variables coefficients in a regression of the probability for making a choice in a particular direction, for example, the probability of choosing the transportation regulation. Alternatively, one could present respondents with a series of tradeoffs until equivalence is achieved. For those who view averting a risk of 2,000 motor-vehicle deaths as being equivalent to averting 1,600 cases of cancer, cancer risks are valued as 2,000/1,600 = 1.25 times as much as transportation deaths.

Because stated preferences are hypothetical expressed preferences, researchers have developed criteria to test for whether respondents have understood the survey task and have provided consistent responses, such as avoiding dominated choices. A principal test is that of scope tests, whereby respondents should be willing to pay more for a larger risk reduction than a smaller risk reduction. Some researchers have suggested that the willingness to pay amounts should be proportional to the risk reduction (Hammitt & Graham, 1999), while others suggest that proportionality is not required based on economic theory and is a very demanding test (Jones-Lee & Aven, 2017). Scope tests can be either internal within subject tests or external across subject tests. There are also behavioral scope tests. For example, stated preference estimates of the VSL should be positively related to the respondent's income level.

Finally, Kling, Phaneuf, and Zhao (2012) suggested the following categorization of validity test criteria. Responses should display convergent validity in that they should be similar to revealed preference evidence. Valuations should satisfy construct validity in that the stated willingness to pay amounts should equal what actual payments would be. Finally, the survey should satisfy content validity as the scenario description, survey structure, and statistical analysis should be consistent with best economic practices.

Use of Survey Methods

Stated preference studies have been used to provide estimates of the VSL both for traumatic fatality risks as well as for illnesses. Even for developed countries the available market data may not be adequate to obtain reliable labor market estimates of the VSL, leading countries such as the United States to rely on stated preference evidence such as the study of transportation safety risks by Jones-Lee, Hammerton, and Philips (1985).

The average VSL implied by the stated preference studies has tended to be less than the revealed preference evidence from labor market studies. The gap is not simply due to income differences across countries, as even the United States VSL estimates from stated preference studies tend to be lower than the labor market estimates (Viscusi, 1993).

The meta-analysis by Lindhjem et al. (2011) provides a review of 856 stated preference studies of the VSL. The mean VSL (in $2005) is $6.1 million, and the median is $2.4 million. The substantial disparity between the mean and the median values is reflective of the right-skewed nature of the VSL distribution. For example, the U.S. VSL estimates in their sample range from $37,222 to $138,000,000. After pruning the VSL estimates at the top 2.5% and bottom 2.5% of the distribution of VSL relative to per capita GDP, the mean-median disparity is diminished but still remains, as the trimmed mean is $5 million, and the trimmed median is unchanged. The gap between the mean and median values is often consequential for policy, as U.K. policymakers selected the median estimate as the policy guide because it was more similar to the previous human capital measures (Jones-Lee & Spackman, 2013). The risk context (environmental, traffic, public, and health) is often consequential, as is whether the health outcome involves cancer, but the results are often sensitive to the particular sample screen.

The reliance on stated preference evidence has led the OECD to propose a VSL range for policy analysis that is substantially below U.S. government practices and revealed preference evidence. In particular, the OECD (2012) recommends that countries use a VSL range from $1.8 million to $5.5 million ($2015). The recommended OECD base value is $3.6 million, which could be adjusted to reflect international differences in the VSL based on country-specific differences in per capita income levels.

Stated preference studies using both risk-dollar and risk-risk tradeoffs have focused on the valuation of different types of death risks, with cancer receiving the greatest attention to date. However, there have also been explorations of other aspect of the risk that may be consequential, such as the dread associated with the risk (Chilton et al., 2006) and the culpability of the person who is subject to the hazard or whether the death is a random isolated incident of a catastrophic event in which a large number of people die (Covey, Robinson, Jones-Lee, & Loomes, 2010; Viscusi, 2009). Stated preference studies have also found that large numbers of deaths from terrorist attacks do not command a premium and that risks from natural disasters appear to be less highly valued perhaps because respondents do not believe that they are directly threatened by the hazards (Viscusi, 2009). The studies of the different types of death risk are often facilitated by the use of risk–risk approaches in which respondents compare a reference risk, usually a traumatic injury such as transportation risks, and a more novel risk, such as cancer, deaths from terrorist attacks, or natural disasters.

How You Die

Application in policy context of the VSL from specific contexts, such as labor market studies, makes a benefit transfer assumption that the willingness to pay for the different types of risk reduction is the same. Assuming that the populations have similar preferences, one would expect that traumatic causes of death would be valued similarly because the morbidity consequences do not differ greatly. For example, there is no statistically significant difference in the labor market estimates of the VSL for transportation and non-transportation related risks (Viscusi & Gentry, 2015).

For other risks of death the composition of the VSL may be consequential. If the utility function associated with death is an additively separable function of the utility of the bequest and the utility of the morbidity loss associated with the fatal event, then the VSL equals the sum of the marginal value of the fatality risk and the marginal value of the morbidity risk (Gentry & Viscusi, 2016). The following model captures the components. Let $p =$ the risk of death, $w(p) =$ the wage rate, $u(w(p)) =$ the utility when healthy, $v(w(p)) =$ the bequest function, and $z(w(p)), t) =$ the morbidity effect of a fatality event that has *t* periods of morbidity effects. Then

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

or

$$VSL = Value\ of\ fatality\ risk\ \ (VFR) + Value\ of\ morbidity\ risk\ (VMR)$$

About three-fourths of the labor market estimates of the VSL are accounted for by the loss on one’s life, with the remainder being attributable to the associated morbidity loss with the fatal event. The loss of life is common to all risks of death so that whether a particular cause of death merits a premium relative to labor market VSL estimates depend on whether the morbidity component of that other cause of death is greater than that associated with traumatic injuries.

Because of the prominence of cancer risks in government regulatory policies, several stated preference studies have sought to determine whether there is a cancer risk premium (Hammitt & Haninger, 2010; Hammitt & Liu, 2004; Magat, Viscusi, & Huber, 1996; McDonald, Chilton, Jones-Lee, & Metcalf, 2016; Van Houtven, Sullivan, & Dockins, 2008; Viscusi, Huber, & Bell, 2014). The studies differ in terms of the types of cancer considered, the morbidity effects of the disease, whether the morbidity effects are discussed in the survey, and the latency period before the illness occurs. None of the studies has indicated that cancer is less highly valued than traumatic injuries. Bladder cancer risks command a premium of about 20% relative to transportation-related deaths. Some cancer risks are more highly valued and others less highly valued. It is not feasible to distinguish whether all of the observed differences are due to differences in stated preference study method and survey structures rather than differences in the health outcome being assessed. Stated preference research on cancer risks and other causes of death with substantial morbidity components will lead to refinement of the differentiation of the VSL estimates across different causes of death.

Government Practices

The practices of U.S. government agencies have evolved from procedures anchored on the human capital approach to use of VSL estimates consistent with findings in the economics literature. The trend in governmental approaches and the convergence to the VSL estimates in the labor market literature is exemplified by the following VSL estimates (all in $2015) for regulatory analyses by branches of the U.S. Department of Transportation. The department evaluated the VSL a regulation in 1985 for protective breathing equipment at $1.3 million (Federal Aviation Administration), a 1990 radar service area regulation at $2.8 million (Federal Aviation Administration), a 1996 aircraft flight simulator regulation at $4.1 million (Federal Aviation Administration), tire pressure monitoring systems regulation in 2000 using a VSL range from $4.3 million to $6.8 million (Department of Transportation), federal motor vehicle standards in 2009 at a range from $6.4 million to $6.7 million (National Highway Traffic

Safety Administration), and flight crew member duty and rest requirements in 2010 using VSL estimates of $6.5 million and $9.3 million (Federal Aviation Administration).

Most U.S. government agencies have now adopted VSL estimates in a similar range consistent with the economics literature. The U.S. Department of Transportation (2016) drew on labor market studies utilizing the CFOI fatality rate data and selected a VSL of $9.4 million. General U.S. Environmental Protection Agency (2016) guidance drawing on revealed preference and stated preference estimates indicates a VSL of $9.7 million. The U.S. Department of Health and Human Services (2016) is less explicit about the source of its estimates but now recommends a value of $9.6 million. Note that these figures are agency guidance amounts and are often not required figures, as different agency branches sometimes select other values.

For the reasons discussed above, countries have adopted relatively low VSL figures as they have relied on stated preference evidence and, in some cases, on the median values rather than the mean estimates from the stated preference studies. For example, the U.K. HM Treasury (2011) recommends that policymakers use a mortality benefits value for transportation regulations of $2.29 million ($2015). Similarly, as noted above, the OECD recommends a base VSL of $3.6 million.

Although government agencies do not generally distinguish different causes of death, there have been attempts to establish a differential premium for risks of cancer. In the United Kingdom, HM Treasury (2011) has advocated that cancer risks receive a VSL that is double the value of accidental risks. There has been no comparable formal premium for cancer risks in the United States, but the U.S. Environmental Protection Agency (2010) has hypothesized that cancer risks should receive a 50% premium relative to traumatic fatalities.

In some situations, government policies will lead to very short extensions of expected lifetimes. For example, if a new prescription drug will lead to an additional year of life expectancy, it is appropriate to value this extension of life at the same level as reducing the mortality risk for someone whose life expectancy is being extended by 60 years through the government policy. To better address very short extensions of life, it is possible to calculate the value of each expected year of life that is implied by the VSL. The amount is the value of a statistical life year, or the VSLY. The relationship between the VSL and the VSLY is as follows. Let L be the life expectancy at the worker's age and r be the discount rate, which authors generally set at values such as 3%. Then, the annualized VSL, or the VSLY, is given by

$$VSLY = \frac{rVSL}{1-(1+r)^{-L}}$$

Although estimates of the VSLY are less commonly used by government agencies than the VSL, there are some regulatory contexts involving very short increases in life expectancy, such as for pharmaceutical regulations. The VSLY estimates used by the U.S. Department of Health and Human Services have risen from $116,000 (U.S. Department of Health and Human Services, 1998) to $369,000 (U.S. Department of Health and Human Services, Food and Drug Administration, 2016). Whereas the earlier VSLY estimates appeared to be arbitrary and without a strong economic rationale, when it increased its VSLY estimates from levels that appeared to be arbitrary placeholders, the agency cited the estimates in Aldy and Viscusi (2008) as the justification for its higher VSLY figure. There is consequently substantial reliance on labor market estimates both for the VSL and the VSLY.

Conclusion and Directions for Future Research

Our purpose in the scheme of the *Encyclopedia* has been to provide a cost-effective yet transcendental tour of the concept of the VSL as the economic valuation of small changes in personal safety risk. In addition to its numerous facets, we document the many foundational applications of VSL in the four pillars of public policy—provision of information to the public, the legal system, regulation, and social insurance. Given that the monetized value of mortality risk reductions is the largest component of all regulatory benefits, the VSL is the most important economic concept for government regulatory policy and is becoming more important in the decisions of private sector firms.

The theoretical underpinnings of VSL flow naturally from the addition of a quality dimension to the exchange of goods and services between people and employers or product producers. In researching the empirical content of the VSL along with its cousins the VSLY and the VSI the preferred choice of most researchers and U.S. policymakers is the revealed preference method wherein the researcher infers the willingness to pay for more or compensation required to accept less safety in the context of actual risk-taking decisions in labor and product markets. We therefore began by presenting the canonical econometric specification used in the literature and its attendant estimates of VSL. Included in the discussion were the preferred econometric specification and key variables' measures along with how VSL varies internationally.

One of the most interesting lines of empirical research in economics is the issue of individuals' heterogeneity and the policy relevance accompanying it. Considerable progress has been made in exploring aspects of heterogeneity, but this remains a fruitful area of research. Among the most prominent aspects of VSL heterogeneity that we touched upon are age variations in VSL and the income elasticity of VSL. The income elasticity is particularly important because it is the key to understanding international differences in VSL and the associated international differences in safety policy as well and indicating adjustments policymakers should make to threshold VSL values due to income growth.

Continuing to explore the issue of the subtleties of the VSL we then turned our attention to the complexities of labor and product markets, which also affect VSL estimates. The willingness to pay for safer products through higher prices for safety features, such as automobile airbags, is another way to estimate the VSL. Corporate decisions concerning product safety and military strategy decisions concerning soldiers' combat deployments can also reveal aspects of the VSL. Markets may be segmented in that not all groups receive the same compensation for risk. Recent immigrants may receive less compensation per unit risk than do native U.S. workers, and there is increasing attention to the emerging themes from behavioral economics. Among the complexities of VSL are the influence of psychological issues such as systematic biases in risk misperceptions, ambiguity aversion, rational ignorance of risk probabilities, loss aversion, and relative position effects stemming from where one is in the wage distribution.

Of somewhat lesser prominence in the empirical literature on the VSL are estimates from survey studies, or the so-called stated preferences approach. Our review of survey methods in the United States, the United Kingdom, and the OECD countries indicated that stated preference estimates are generally lower than revealed presences measures, which are themselves a controversial approach to econometricians.

Exploration of a discrepancy in the VSL from revealed versus stated preferences data and potential biases that might arise from reliance on one of the approaches versus the other might be consequential, particularly for countries for which the revealed preference data on risk-taking behavior are not reliable. For purposes of discussion, let us assume that the revealed preference data constitute the most meaningful reference point for establishing the VSL when appropriate data exist. If countries choose to rely on stated preference values despite the sometimes inadequacy of workplace fatality rate data, what biases are introduced by doing so, and what is the source of the biases? Stated preference studies inform respondents of the actual risk levels so presumably there should be less measurement error in the risk variable than in revealed preference studies. If the error in revealed preference studies is random, then revealed preference estimates should be lower than the stated preference study estimates rather than the higher values that are often observed. Similarly, revealed preference studies draw on populations that have self-selected into risky pursuits, which likewise should tend to lead to lower revealed preference values instead of the higher values that are observed. Do the lower VSL estimates in stated preference studies stem from respondents not finding hypothetical risks in survey contexts to be fully credible? Or, perhaps they view the survey scenarios as pertinent to others in the population but not to them. Trying to resolve the disparity in revealed preference evidence and stated preference evidence is of continuing importance given the varying emphasis countries place on the two different sources of VSL estimates, particularly outside of the United States.

Another emerging topic we have addressed here are the links among the VSL, how one may die, and safety regulations and policy. The additional heterogeneity of the VSL and its implications we considered include death from natural disaster, terrorist attack, automobile accident, or cancer. What are the morbidity versus mortality components of the VSL? Should there be a premium component to the VSL used for risk of death by cancer when exposed to carcinogens at work or based on where you live are things we have considered. With respect to such possibly variations in values based on the nature of the death, we discussed government practices in the United States for using the VSL in transportation and environmental regulations.

Policy practices also may differ across agencies and have yet to be perfected. What kind of evidence should be used in setting the agency's VSL? Should the agency rely on revealed preference evidence alone, as does the U.S. Department of Transportation, or should stated preference evidence also be considered, as does the U.S. Environmental Protection Agency? Even if the choice of the type of study has been resolved, which estimates from within that class of studies should the agency use in setting the VSL? Does the credibility of the estimates and the reliability of the risk variable matter, and what criteria should be used to assess credibility and reliability? For example, should agencies use the best estimate overall in the literature or the single best estimate from a series of studies and then pool these estimates in some fashion? If the different types of evidence are combined in some manner, how should it be done? Should the agency take a simple average of the most credible estimates or should it adopt a meta-regression approach that controls for different study characteristics? If a meta-regression approach is used, should there also be an adjustment for potential publication selection biases or is it sufficient to rely on the studies least subject to such biases? There has been increasing attention to such issues in the academic literature and decisions regarding these matters are implicit in some agency practices. However, there has yet to emerge an international consensus among policymakers on the most pertinent approach for agencies and different governments to use in establishing the VSL for policy evaluations.

We ended with a look to the aspects of VSL that will be likely to be of interest to researchers and policymakers in the future. There is the issue of the term value of a statistical life itself and its possible emotional complications. Should the government adopt a possibly confusing alternative such as the value of mortality risk reduction (VMRR), which undermines the potential role of the VSL in valuing mortality risk increases? Or should economists do a better job of explaining the generality of an ex ante *statistical* life as the measure of individuals' willingness to pay for more safety or compensation needed to accept less safety or more fatality risk? An emerging push toward evidence-based policy should widen and deepen the use of VSL estimates. Enhanced policy relating to risk equity will also continue to develop attention as well as clarifying possible inefficiency causing regulatory misapplication of VSL. A controversial aspect of heterogeneity in the VSL involves the application of the VSL concept to children with no clear line of research and regulatory consequences yet emerging.

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