MONTHLY LABOR REVIEW

October 2013

Using data from the Census of Fatal Occupational Injuries to estimate the "value of a statistical life"

The advent of the Census of Fatal Occupational Injuries has enabled researchers to reduce measurement error in fatality rate estimates; in turn, estimates of the "value of a statistical life" that are based on labor market data have become less uncertain.

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Occupational fatality rate data sometimes have been used to estimate the tradeoff between worker wages and fatality risks. In this regard, a key question is, "Controlling for other aspects of the job and characteristics of the worker, what additional pay do workers receive for bearing greater risks?" This tradeoff rate, which has come to be known as the *value of a statistical life* (VSL), equals the extra amount of wages workers require per expected workplace fatality. For the past three decades, government agencies have used VSL estimates to monetize the mortality reduction benefits of health, safety, and environmental regulations.[1] Labor market estimates of the VSL provide a measure of workers' revealed preferences for the valuation of risk. Estimating the VSL on the basis of actual risk-taking behavior yields potentially more meaningful estimates than stated preferences with respect to hypothetical risks described in a survey context.

The extensive labor market literature generating estimates of the VSL has utilized several fatality rate measures, which typically are matched to employment information on individual workers that is reported in large datasets. These fatality rates have included various Bureau of Labor Statistics (BLS) fatality rates by industry, fatality rates from the National Traumatic Occupational Fatality database of the National Institute of Occupational Safety and Health, insurance company fatality rates by occupation, and fatality rates derived from workers' compensation records. The most common approach has been to match fatality rates by industry to the industry reported by the worker in the survey, although some studies instead have used occupational risk data to match risks to workers by occupation. The compensating differential studies utilize a wage equation or the logarithm of a wage equation to estimate the additional premium workers receive for risk, controlling for other wage determinants. This premium per unit risk is the VSL.

Ideally, the fatality rate measure used in any analysis should reflect the riskiness of the worker's job. However, the fatality rate variables used in the VSL studies typically have been imperfect proxies for the worker's risk level. In addition, there are several sources of measurement error in the fatality rate data, and this error in turn may create a bias in wage equation estimates of the VSL.[2] First, the fatality rate measure may not pertain only to job-related risks, as happened in the case of studies that used mortality rates of people in different occupations, independently of whether the death was job related. Second, early BLS estimates of fatality rates by industry relied on voluntary reporting and a limited sample of firms, potentially influencing the estimates. Finally, even if the industry fatality rate is measured accurately, not all workers in that industry face the same fatality rate, so occupational differences in risk also should be taken into account.

The advent of the BLS Census of Fatal Occupational Injuries (CFOI) alleviated these and related shortcomings of fatality rate measures. The CFOI data series is a comprehensive census of all job-related fatalities, which are verified through multiple sources of information, such as accident reports, coroners' reports, and workers' compensation records. The information on each fatality includes diverse personal characteristics data, as well as details regarding the nature of the incident and the type of injury. As a result, it is possible to develop much more refined measures of the fatality rate than would be possible on the basis of an overall industry average. Also, these measures can be tailored to the concerns of the particular study by, for example, conditioning the fatality rate on gender or age. Note that, because accidents are more readily monitored than job-related illnesses, particularly those with a long latency period for which causality may be difficult to determine, the CFOI data are best suited to analyses of acute fatality risks.

Fatality rates by industry and occupation

A breakdown of CFOI risk levels that is useful in empirical work is a matrix of the risks by industry and occupation. Industry risk levels are still the primary focus of most analyses because there is less measurement error in workers reporting their industry than their occupation,[3] but utilizing risk measures that incorporate some differentiation in risk levels by broad occupational group remains desirable in order to capture occupational variation in riskiness. For the early years of CFOI data, the industry codes were the Standard Industrial Classification (SIC) codes and the occupation codes were the U.S. Census Bureau codes. Beginning in 2003, the CFOI adopted the North American Industrial Classification codes for industries and the Standard Occupational Classification codes for occupations, and some additional changes were made starting in 2011. To avoid the greater measurement error problems associated with individuals' reported occupations, most industry–occupation breakdowns appearing in the literature have utilized relatively refined groupings of 50–72 industries coupled with higher level groupings of about 10 major occupations.

Table 1 provides summary fatality rate measures by industry and occupation for an illustrative set of 10 nonagricultural industries and 10 occupations. The measures were constructed with the use of CFOI fatality data from 2003 to 2008 in conjunction with hours-weighted employment data based on Current Population Survey (CPS) Merged Outgoing Rotation Groups (MORGs).[4] Average hours were calculated by industry, occupation, and year. In 2007, the BLS released both an hours-weighted approach to calculating the fatality rate and the employment-based approach it had been using until then. The BLS moved completely to the hours-based approach in 2008. The estimates in table 1 incorporate the hours-based methodology.[5] Only workers in the age range from 16 to 64 years are included. Using multiple years of data reduces the influence of random year-to-year fluctuations in fatalities—fluctuations that may be particularly problematic for small industry–occupation cells. In 10 instances in table 1, the risk level is not reported because values did not meet BLS publication criteria.

Table 1. Fatality rates, by industry and occupation, 2006–2008

Occupation	Industry										
	Total	Construction	Finance, insurance, and real estate	Information	Manufacturing	Mining	Public administration	Retail trade	Services	Transportation and public utilities	Wholesale trade
Management, business, and financial	1.2	3.8	0.8	0.6	0.7	3.2	0.9	0.7	1.1	1.3	1.5
Professional and related	.9	3.5	.2	1.1	.7	7.2	1.2	.7	.8	1.5	1.3
Service	3.2	16.2	2.8	2.0	1.9	(1)	9.1	2.1	2.4	2.9	(1)
Sales	1.9	1.9	1.1	2.1	1.7	(1)	(1)	2.3	1.1	1.0	2.1
Office and administrative support	.5	.6	.3	.4	.4	(1)	.3	.6	.4	1.4	.5
Farming, fishing, and forestry	8.3	(1)	(1)	(1)	6.7	(1)	10.3	8.6	19.4	15.5	4.6
Construction and extraction	12	11.8	4.8	(1)	6.6	34.9	5.0	3.1	12.4	8.4	8.4
Installation, maintenance, and repair	6.9	13.8	6.2	3.6	6.0	16.5	1.9	3.0	6.2	8.9	11.7
Production	2.8	14.1	3.2	2.0	2.4	16.1	2.8	1.1	2.8	4.1	7.0
Transportation and material moving	15.8	21.6	15.3	28.2	7.9	25.4	13.9	5.7	14.1	22.4	11.4
Industry average	…	10.2	1.0	1.7	2.4	20.7	3.9	2.1	1.8	11.5	4.0

Notes:

(1) Data did not meet BLS publication criteria.

Note: Fatal injury data were obtained with restricted access to the Census of Fatal Occupational Injuries research file.

Source: U.S. Bureau of Labor Statistics.

Both the average industry risks and the average occupational risks exhibit substantial variation across the sample. The average fatality rates by industry per 100,000 workers range from 1.0 to 20.7, and the average occupational fatality rates range from 0.5 to 15.8. There is also considerable within-industry variation in risk by occupation. In the case of the construction industry, for example, the fatality rate per 100,000 workers ranges from 0.6 for office and administrative support workers to 21.6 for transportation and material moving occupations.

The manner in which researchers choose to refine the fatality rate measure depends in part on the focus of the research. The fatality rate dimensions that have been considered by different studies in the CFOI literature include industry, occupation, age, race, immigrant status, and type of accident, as well as various interactions among these dimensions. At the extreme, one could analyze risk levels defined on all of the dimensions. However, doing so will create a large set of fatality rate categories, leaving many empty cells, as well as many other cells with low risk levels that are measured imprecisely.

Using the CFOI to estimate the VSL

Economists estimate the VSL by matching fatality rate data to workers in large employment datasets on the basis of worker characteristics. Tables 2 and 3 use 2008 CPS data in which each worker is matched with the pertinent industry–occupation fatality rate calculated for each of 50 industries and 10 occupational groups. Table 2 summarizes some sample characteristics. The standard procedure is to estimate a regression equation in which the hourly wage or the logarithm of the hourly wage is the dependent variable. The set of explanatory variables included a variety of personal and job characteristics.[6] The sample is restricted to full-time nonagricultural workers.

Table 2. Selected sample characteristics

Variable	Mean	Standard deviation
Hourly wage	20.88	12.51
Logarithm of hourly wage	2.88	.55
Age	41.05	11.86
Gender (1 = male)	.55	.50
Marital status (1 = married)	.59	.49
Race (1 = White)	.83	.38
Union (1 = member)	.15	.36
Years of schooling	14.77	2.57
Average number of hours per week	42.57	6.41
Fatality rates (per 100,000):		
Employment-based fatality rate	3.41	6.23
Hours-based fatality rate	3.29	5.60
Sample size	126,225	…

Source: Author's calculations, based on U.S. Bureau of Labor Statistics, Current Population Survey.

The estimates in table 3 are of particular interest in that they comprise estimates based on the new hours-based fatality rate approach as well as estimates based on the earlier employment-based fatality rate. All studies using CFOI data to estimate the VSL are based on the previous employment-based measure, so it is worthwhile to assess whether the fatality rate measure influences the estimates. The hours-based fatality rate is somewhat lower than the employment-based rate. The hours-based fatality rate is 3.29 per 100,000 workers for the sample used in the estimation and 3.53 for the 2008 CPS more generally. By comparison, the employment-based rate is 3.41 for the sample and 3.66 for the 2008 CPS.

Table 3. Regression estimates of the value of a statistical life

Category	Wage equation, based on—		Logarithm of wage equation, based on—	
	Hours-based fatality rates	Employment-based fatality rates	Hours-based fatality rates	Employment-based fatality rates
Fatality rate	0.0395 (0.0078)	0.0437 (0.0067)	0.0024 (0.0003)	0.0026 (0.0003)
Value of a statistical life (in millions of dollars)	7.9	8.7	9.9	11.1
Adjusted R-squared	.3884	.3885	.4405	.4407

Note: Standard errors are in parentheses following the estimate. All coefficients are statistically significant at the 99-percent level or better. Endnote 5 in the text gives other variables included in the equation. The sample size is 126,225.
Source: Author's calculations, based on U.S. Bureau of Labor Statistics, Current Population Survey.

As the results shown in table 3 indicate, the fatality rate variable is positive and statistically significant in each case. Calculating the VSL on the basis of the estimates obtained from the wage equation entails multiplying the fatality rate coefficient by 100,000 (because the fatality rate is expressed per 100,000 workers) and by the average number of hours worked per year, to convert the hourly wage into an annual compensation amount.[7] The calculation of the VSL for the logarithm of the wage equations is similar, except that the estimates also must be multiplied by the average hourly wage rate.

The VSL estimates in table 3 range from $7.9 million to $11.1 million. The estimates based on the hours-based fatality rates are $0.8 million to $1.2 million smaller, but the confidence intervals for the VSL estimates overlap. Although there is a consistent difference, the narrowness of the gap is indicative of the relative stability of the VSL estimates, whether the hours-based fatality rate or the employment-based measure is used.

Previous studies using the CFOI to estimate the VSL

To date, 16 previous studies have used CFOI data. Table 4 summarizes some of the principal characteristics and results of these studies. In addition to listing the particular study, the CFOI measure used in the analysis, and the employment sample, the table reports one or more empirical estimates of the VSL (in 2012 dollars) from the article in question, based on representative log–wage equations estimated in the article. All of the articles listed report many different estimates of the VSL, in one case as many as 80 different equations. All but one of the articles match CFOI risk variables to individual employment data, rather than industry averages. Studies based on individual data control for a detailed set of personal characteristics and job characteristics. The lone exception to the use of microdata is the article by William P. Jennings and Albert Kinderman, which analyzes average industry wage rates rather than utilizing a large sample of individual data, as is the norm in the labor economics literature.[8] The model set forth by those authors, which includes no controls for worker characteristics or job characteristics other than average industry risk levels, yielded no significant evidence of aggregate premiums for risk across broad industry groups.

Table 4. Labor market estimates of the value of a statistical life (VSL), based on data from the Census of Fatal Occupational Injuries (CFOI)

Study	CFOI measure	Worker sample	Representative VSL estimates (millions of dollars)
Viscusi (2003)	Industry–race, 6-year average	CPS (1997), 20 equations	$21.5 Whites (full sample) 10.3 Blacks (full sample)
Leeth and Ruser (2003)	Occupation–gender–race, 3-year average	CPS (1996–1998), 28 equations	6.0 (risks, by occupation, men)
Jennings and Kinderman (2003)	Industry	Occupational Employment Statistics survey, 1992–1999, 1 equation at industry level	No significant effect
Viscusi (2004)	Industry, occupation, and industry–occupation annual and 6-year averages	CPS (1997), 80 equations	6.7 (full sample) 10.0 (blue-collar men) 12.2 (blue-collar women)
Kniesner and Viscusi (2005)	Industry–occupation, 6-year average	CPS (1997), 6 equations	6.7 (full sample) 6.9 (male sample)
Kniesner, Viscusi, and Ziliak (2006)	Industry–occupation	PSID (1997), 10 equations	12.8 (base case with industry controls)
Viscusi and Aldy (2007)	Industry–age, 6-year average	CPS (1998), 20 equations	7.8 (ages 55–62) 16.4 (ages 35–44)
Viscusi and Hersch (2008)	Industry–age–gender, 6-year average	CPS (1996), 4 equations	9.8 (nonsmokers) 9.7 (smokers)
Aldy and Viscusi (2008)	Industry–age	CPS (1993–2000), 8 equations	6.4 (full sample) 5.0 (ages 18–24) 12.8 (age 35–44) 4.6 (age 55–62)
Kniesner, Viscusi, and Ziliak (2010)	Industry–occupation	PSID (1993–2001), 5 quantile equations	9.8 (median)
Evans and Schaur (2010)	Industry–age	HRS (1994-1998), 5 quantile equations, 1 ordinary least squares equation	20.7 (mean for 50-year-olds)
Hersch and Viscusi (2010)	Industry–occupation–age–immigrant status, 3-year average	New Immigrant Survey (2003); CPS (2003), 22 equations	11.0 (native-born U.S. workers), 6.6 (immigrant workers)
Kochi and Taylor (2011)	Accident or homicide, by metropolitan statistical area, for drivers	CPS (1996–2002), 13 equations	6.1–8.4 range
Scotton and Taylor (2011)	Industry–occupation, 6-year average	CPS (1996–1998), 9 equations	12.3 (undifferentiated deaths)
Kniesner, Viscusi, Woock, and Ziliak (2012)	Industry–occupation, annual and 3-year averages	PSID (1993–2001), 59 quantile equations	11.4 (static first differences)
Kniesner, Viscusi, and Ziliak (2012)	Industry–occupation, annual and 3-year averages	PSID (1993–2001), 40 equations	13.0 (first difference for job changers, 3-year average risk)

Note: CPS = Current Population Survey; PSID = Panel Study of Income Dynamics. All VSL estimates are in 2012 dollars. Authors and years cited reference the following works in the literature: Viscusi (2003): W. Kip Viscusi, "Racial differences in labor market values of a statistical life," *Journal of Risk and Uncertainty*, December 2003, pp. 239–256; Leeth and Ruser (2003): John D. Leeth and John Ruser, "Compensating wage differentials for fatal and nonfatal injury risk by gender and race," *Journal of Risk and Uncertainty*, December 2003, pp. 257–277; Jennings and Kinderman (2003): William P. Jennings and Albert Kinderman, "The value of a life: new evidence of the relationship between changes in occupational fatalities and wages of hourly

See footnotes at end of table.

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The average overall level of the VSL from the more conventional econometric analyses is in the general range of previous VSL estimates. Using risk measures extant before any CFOI data were available indicates that the median labor market estimate based on a meta-analysis of the literature was $9.3 million.[9] The estimates in table 4 are fairly similar, with some being higher than that value and some lower. The VSL is not a universal constant but reflects the heterogeneity of worker preferences. Thus, the estimates will vary across different samples and over time for similar samples. Differences in econometric specifications, such as the inclusion of nonfatal risk variables in the analysis, also may be influential. Many differences in VSL levels found across studies arise from differences in the job match analyzed, because the estimated risk–money tradeoff rates will embody the influence of differences in worker preferences as well as differences in the marginal cost of providing greater safety across jobs.

The range of estimates based on the CFOI data is narrower than in the literature generally, particularly for studies that include detailed sets of controls to isolate the wage–risk premium. The greater credibility of VSL studies based on CFOI data has begun to be reflected in government practices with respect to the valuation of mortality reduction benefits. The U.S. Department of Transportation now bases its assessments of mortality risks on VSL estimates that use results from the CFOI data.[10] More specifically, the Department established its VSL estimate by averaging a set of CFOI VSL estimates from nine of the studies listed in table 4 and concluded that the most pertinent VSL for mortality risk assessment is $9.2 million. This estimate is near the median value from the previous literature but higher than most VSL levels currently used in the federal government. Part of our refined understanding of the VSL is that these new results also make it possible to narrow the range of VSL estimates, reducing the range of uncertainty for this key statistic.

Perhaps the principal dividend derived from using the CFOI data is not in estimating an average value for the VSL but rather in greatly expanding the range of our understanding of the functioning of labor markets with respect to job risks. The final column of table 4 indicates that studies have generated VSL estimates not just for an economywide average but also for specific groups within the labor market.

Use of the CFOI with panel data

Panel data offer the opportunity to control for time-invariant fixed effects as well as differences in wage growth over time. In addition, panel data make it possible to explore the locus of compensating differentials in the workplace. Do these risk premiums arise for changes in risk affecting workers within their current jobs, or do workers receive premiums largely for differences in riskiness when changing jobs? Panel data from the Panel Study of Income Dynamics (PSID) also make it possible to explore possible sources of the relatively high VSL estimates found in some cross-sectional studies that used the PSID data and to control for person-specific effects that may give rise to VSL outliers.

Before the advent of the CFOI data, only a couple of studies attempted to analyze the VSL in a panel context. Their efforts were hampered by the availability of fatality rate data only by industry or only by occupation. For example, for fatality rate data by occupation, workers who change industries, but not occupations, will be assigned to the same fatality rate category. If, then, as in one such study, the occupational risk data are for a single year only, all workers who do not change occupations will be assigned the same risk level, so their assigned risk change over time will be zero when, in fact, their actual risk change may not be.

The ability to use the CFOI to construct annual fatality rates that vary by industry and by occupation makes it possible to incorporate risk changes over time that could occur in either of two ways. First, the estimated risk for the worker's job may change because the worker has taken a job in a different industry or occupation. Second, the estimated risk could change over time even if the worker has not changed jobs and moved to a different industry–occupational group, as long as there has been a change in the risk for the particular industry–occupational group in which the worker is employed. In regard to these two possibilities, Thomas J. Kniesner, W. Kip Viscusi, Christopher Woock, and James P. Ziliak found that differences in risk levels, as well as most evidence of premiums for risk, arise for workers changing jobs rather than for workers who remain in their current jobs.[11] Controlling for worker heterogeneity in the panel study also greatly reduces the variance in the VSL estimates, enabling researchers to pin down the estimates with greater precisions. Across a wide range of reasonable specifications, Kniesner and his colleagues found that VSL estimates are clustered in the range from $4 million to $10 million (2011 dollars). In its guidance document on selecting the VSL for the purpose of reducing fatalities and injuries by regulations or investments, the Department of Transportation adopted the range from $5.2 million to $12.9 million (2012 dollars) as the range of uncertainty for the VSL.[12] As a result, in selecting a relevant range of VSL values, the Department relied on a series of VSL estimates that use only the CFOI data.

Using CFOI data in conjunction with panel data also facilitates analyzing potential asymmetry in the VSL for workers who are moving to safer jobs as opposed to workers moving to riskier jobs. Experimental results indicate a profound gap between the willingness-to-pay values and the willingness-to-accept values, with the average willingness-to-accept value 7 times greater than the willingness-to-pay value. If similar differences hold true in the labor market, then compensating differentials for workers facing an increase in risk will tend to overstate the VSL. Kniesner, Viscusi, and Ziliak presented empirical estimates which indicate that there is no significant difference in VSL levels whether workers who change jobs are incurring increases in risk or obtaining decreases in risk, because the wage–risk tradeoffs are similar irrespective of the direction of change in the worker's job risk.[13] These results provide a test of the general theoretical underpinnings of the VSL analysis, namely, that the tradeoff rates between wages and changes in risk should be the same for small changes of risk levels in each direction.

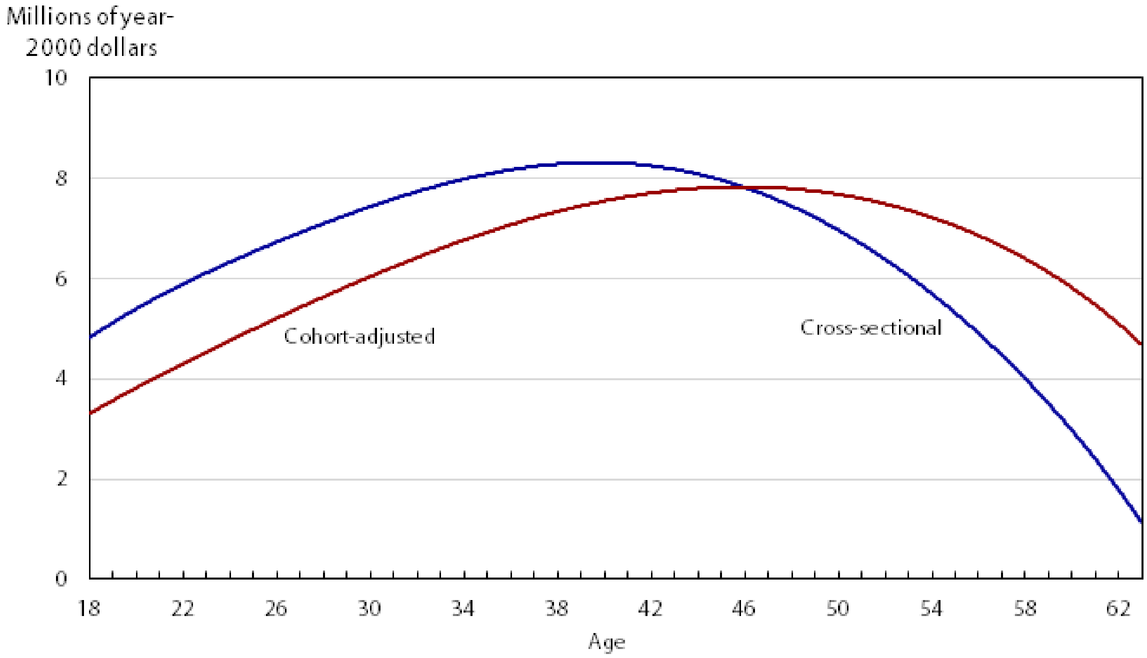
Age variations in the VSL

Lives at risk vary in many dimensions, but perhaps the most fundamental is age. The length of life at risk decreases as one grows older. Consequently, estimates of the VSL are not valuing the same future life at risk for workers of different ages, and there is no economic rationale for assuming that the VSL remains constant over one's lifetime. How the VSL varies with age has been a focus of much theoretical analysis, empirical work, and normative discussion.

A proper understanding of the age–VSL linkage requires that one also understand the relationship between age and fatality rates. There are age differences in risk because the types of jobs workers accept differ with age and because the riskiness of any given job changes with the worker's age. Before the advent of the CFOI data, estimates of age variations in the VSL were based on econometric models in which the fatality rate for the worker's industry was the same for all workers in that industry. However, this invariance of risk with respect to age is not borne out in practice: both nonfatal job injury rates and fatal job accident rates change with age—the one declining, the other increasing. The reason is that, although older workers do not gravitate to jobs that one might consider dangerous, such as mining or high-rise construction work, they are more vulnerable to common sources of job fatalities, such as transportation-related deaths. Perhaps contrary to one's expectations given that younger workers typically work on the most unpleasant and physically demanding jobs, older workers face greater fatality rates than younger workers do. This finding, from Viscusi and Joseph E. Aldy,[14] holds across industries. What does vary with the industry, however, is the steepness of the age–risk gradient, with high-risk industries, such as transportation, posing especially large risks for older workers and comparatively safe industries, such as services and financial industries, having a relatively flat relationship between fatality rates and age.

The failure to account for age differences in riskiness will consequently understate the risk level of older workers in a standard hedonic wage model, thus biasing the VSL estimates. Given this limitation, studies of the VSL–age relationship that were carried out before the advent of the CFOI generally did not explore the age-related pattern in detail but instead assessed a constant average value per statistical life year. Of course, this approach does provide some insight into the average influence of age, but by construction, a model based on a constant value per statistical life year will imply a declining value of the VSL as a person ages and, concomitantly, his or her remaining life expectancy is reduced. Note, however, that the assumption that risks to each year of life are equally valued may not hold, because there are many economic and personal factors that may alter a person's willingness to bear risk over the life cycle.

Figure 1. Cohort-adjusted and cross-sectional value of a statistical life, 1993–2000



Source: Joseph E. Aldy and W. Kip Viscusi, "Adjusting the value of a statistical life for age and cohort effects," *Review of Economics and Statistics*, August 2008, pp. 573–581, figure 1.

The empirical evidence based on using both age-specific fatality rates and the CFOI data indicates that the VSL exhibits an inverted-U-shaped pattern over the life cycle, such as that shown in Figure 1.[15] The main focus here will be on the results that adjust for cohort-related differences. The consistent pattern is that the VSL is at a relatively low level for workers ages 18–24, after which it rises, reaching a peak for workers ages 35–44, and then declines. But this decline is not as steep as the rise between ages 24 and 35, because the VSL for workers ages 55–62 is greater than that for new entrants to the labor force. The overall trajectory of the VSL mirrors the life-cycle pattern of consumption, which is in fact a strong predictor of the VSL. In a world in which it is not possible to borrow and lend with perfect markets, this similarity of the VSL to overall patterns of consumption is consistent with economic predictions.

A person's VSL corresponds to his or her willingness to pay to reduce the risk of incurring a workplace fatality, and, as with other economic choices, it should vary with one's economic circumstances over the life cycle. Kniesner, Viscusi, and Ziliak estimated a strong statistical relationship between the VSL and personal consumption levels over the life cycle.[16] The pattern seen in this relationship is similar to the life-cycle pattern of income levels. That is, a person's willingness to buy greater levels of safety, as reflected in the VSL, varies over the life cycle in much the same way as do expenditure decisions generally.

The failure of the VSL to decline steadily with age also has ramifications for how workers value different years of life. For such a pattern to hold, it cannot also be the case that risks to all years of life are valued equally. Estimates by Aldy and Viscusi using the CFOI data indicate that the value of a statistical life year (VSLY) rises and falls with age, as does the VSL.[17] But the VSLY trajectory is somewhat different, in that it reaches a peak at a greater age than does the VSL. These results have implications for the appropriateness of benefit assessment approaches that assume a constant value per year of life, such as quality-adjusted life years.

Segmented markets by race and immigrant status

The conventional hedonic model of compensating differentials for job risks assumes that all workers are making choices from the same available set of jobs. Although there could be differences in wage levels because of, for example, differences in education, the standard assumption is that the premium offered for risk follows a common trajectory for all workers. If this assumption is true, then workers facing greater risk levels should receive greater additional wage compensation than workers facing lower risk levels. By contrast, the falsity of the assumption would be an indicator that workers are dealing with separate, distinct sets of labor market opportunities.

Two prominent examples in which CFOI data indicate the presence of such segmented labor markets involve differences by immigrant status and differences by race. Interestingly, the information included in the CFOI data makes it possible to condition the fatality rate variable on immigrant status as well as other job dimensions. Using CFOI data to construct fatality rates by industry–immigrant status–age, Joni Hersch and Viscusi found that, for the CPS sample, immigrants face greater risks (5.10 fatalities per 100,000 workers) than do native U.S. workers (4.35 fatalities per 100,000 workers).[18] Within the immigrant population there is considerable variation in risk, with Mexican immigrants facing an average risk of 5.97 fatalities per 100,000 workers while non-Mexican immigrants face an average risk of 4.38 fatalities per 100,000 workers (a rate roughly equal to that of native U.S. workers).

The evidence with respect to compensating differentials received for the risks incurred by workers likewise reflects a disparity between legal Mexican immigrants and other labor market groups. Although there are compensating differentials for these risks, Mexican immigrants in particular receive very low levels of compensation, with no evidence of positive compensating differentials. Similarly, using fatality rate data that account for the worker's race as well as the worker's industry or occupation, researchers have shown that African American workers face greater risks than do White workers. However, as in the case of Mexican immigrants, African American workers receive less in total wage premiums for accepting these risks.[19] Indeed, in some specifications there is no evidence of any statistically significant premiums for accepting risk.

These and related examinations of labor market performance, facilitated by the capabilities of CFOI data, may have profound implications for our understanding of shortfalls in labor market functioning. Disadvantaged labor market groups, such as Mexican immigrants and African Americans, face a challenging set of labor market opportunities in which they incur inordinately high fatality rates. One would expect substantial wage remuneration for accepting such high rates, yet for these groups, there is no evidence of any wage premiums. Even in situations in which they receive some additional compensation for bearing the high risk, the terms under which they do so are less desirable than those of workers who face a different set of options.

Further refinement of the various analyses undertaken sometimes helps to pinpoint some of the problematic aspects of risk in the labor market. The absence of evidence of any statistically significant risk premiums received by Mexican workers who do not speak English highlights a potential gap in the functioning of labor markets and, therefore, a potentially promising area for government regulation, which has been a continuing focus of efforts by the U.S. Department of Labor.[20]

Income-related variations in the VSL

If safety is a normal good, preferences for safety should increase with income levels. As a result, the compensation that more affluent workers require to be willing to bear risk will be greater, thus boosting their VSL. However, meta-analytical evidence across studies undertaken before the use of CFOI data indicate a less-than-proportional relationship between income and VSL, with elasticities in the range from 0.5 to 0.6.[21]

In contrast, more recent studies using the CFOI data, in conjunction with quantile analyses of how the VSL varies across the wage distribution, indicate a greater responsiveness of the VSL to income. The average income elasticities estimated by Kniesner, Viscusi, and Ziliak and by Mary F. Evans and Georg Schaur are greater than 1.0, implying that the VSL likely is more elastic than has been found in the across-study meta-analyses.[22] Thus, both the meta-analytical results and the more recent quantile estimates suggest that increases in income lead to higher VSL levels. As a practical matter, although government agencies do not differentiate VSL levels across the population at a point in time, income elasticities do come into play with respect to how those agencies update VSL estimates over time in order to reflect societal income levels.[23]

VSL estimates by gender, type of risk, and smoking status

The CFOI data also facilitate analyzing variations in the VSL for different worker groups and different types of risk. Thus far, the studies have focused on variations by gender, type of fatality risk, smoking status, and relative position of the worker in the income distribution, largely because these dimensions are often of particular economic interest. Other explorations based on differently constructed fatality rate measures are possible and surely will follow in future research.

In the workplace, women generally face lower job-related risks of injury and death than do men. The evidence with respect to the level of compensating differentials that female workers receive for nonfatal risks is quite strong, perhaps in part because women are compensated for injuries suffered on the job at a rate comparable to that of men.[24] However, job-related fatality rates for women are much lower than those for men, making estimates of women's fatality rates less precise than estimates of men's rates. This precision issue may be exacerbated for gender-specific risks by occupation rather than by industry. In sum, there is some evidence of positive VSL estimates for women, but the evidence reported in CFOI studies such as that by John D. Leeth and John Ruser is less strong than it is for men. Moreover, because women workers receive lower wage rates than men, the VSL estimates for women are also somewhat lower than those for men.[25]

One type of job-related fatality that has received particular attention is homicides. Carol R. Scotton and Laura O. Taylor have found that the implied VSL is different for job-related homicides than for other causes of death.[26] A related study by Ikuho Kochi and Taylor found evidence of a positive VSL value for homicide rates for drivers, such as taxi drivers, but no evidence of a positive VSL for the accident risks facing these workers.

THE RECENT SET OF STUDIES OF THE VSL and, more generally, of the labor market role of risk has refined estimates of the VSL in a variety of ways. The availability of the CFOI data, representing a considerable advance over previously available data, has reduced measurement error, in turn substantially narrowing the range of uncertainty in VSL estimates that are based on labor market data. The decision by the Department of

Transportation to base its VSL estimates on only those studies using the CFOI data is a reflection of the substantial credibility of that dataset.

An additional dividend of the CFOI data is that these new data have made it possible to greatly expand the scope of economic analyses. A noteworthy feature of the data is that information is available on an individual fatality basis, making it possible for researchers to construct different fatality rate measures for alternative lines of inquiry. As a result, it has been possible to obtain more meaningful estimates of how the VSL varies with age and other personal characteristics. It is also now possible to assess which workers within an industry are at particular risk. In conjunction with evidence on whether these at-risk workers receive compensation for accepting the risks, the studies are useful as well in highlighting those disadvantaged labor market groups for whom the functioning of labor markets may fall short.

ACKNOWLEDGMENT: Elissa Philip provided valuable research assistance in the preparation of this article.The article is a revised version of a paper presented at the Bureau of Labor Statistics (BLS) Occupational Safety and Health Statistics special conference held in Washington, DC, on May 15–16, 2013. The research involved was conducted under restricted access to BLS data.The views expressed here do not necessarily reflect the views of the BLS.

NOTES

[1] See W. Kip Viscusi, *Fatal tradeoffs: public and private responsibilities for risk* (New York: Oxford University Press, 1992), for a discussion of the U.S. Department of Labor's disagreement with the U.S. Office of Management and Budget over a proposed Occupational Safety and Health Administration hazard communication regulation.

[2] Among the more recent thorough explorations of some of the measurement error problems are Dan A. Black and Thomas J. Kniesner, "On the measurement of job risk in hedonic wage models," *Journal of Risk and Uncertainty*, December 2003, pp. 205–220; and Orley Ashenfelter, "Measuring the value of a statistical life: problems and prospects," *Economic Journal*, February 2006, pp. C10–C23.

[3] Wesley Mellow and Hal Sider, "Accuracy of response in labor market surveys: evidence and implications," *Journal of Labor Economics*, October 1983, pp. 331–344.

[4] According to the National Bureau of Economic Research, MORGs "are extracts of [CPS] Basic Monthly Data [obtained] during the household's fourth and eighth month in the survey, when [questions about] usual weekly hours/earnings are asked." (See "Current Population Survey (CPS) Data at the NBER" (Cambridge, MA: National Bureau of Economic Research, updated daily).)

[5] The procedure followed in the hours-based methodology is described in footnote 2 of "Fatal occupational injuries, annual average hours worked, total employment, and rates of fatal occupational injuries by selected worker characteristics, occupations, and industries, 2007" (U.S. Bureau of Labor Statistics, 2007), www.bls.gov/iif/oshwc/cfoi/cfoi_rates_2007h.pdf.

[6] More specifically, the variables were potential work experience, potential work experience squared, years of education, and indicator variables for male, married, Black, Native American, Asian, Hispanic ethnicity, doctorate or professional degree earned, paid hourly rate, full-time employment, union or employee association membership, government employment, six metropolitan and nonmetropolitan areas, eight regional areas, nine largely blue-collar occupations, and professional occupational group. The sample is restricted to those working at least 35 hours per week with hourly wages between $2 and $100. Excluded are workers in agriculture and those in the Armed Forces.

[7] For both the employment- and hours-based measure, the annual number of hours is 2,000, representing a standard 40 hours per week for 50 weeks.

[8] William P. Jennings and Albert Kinderman, "The value of a life: new evidence of the relationship between changes in occupational fatalities and wages of hourly workers, 1992 to 1999," *Journal of Risk and Insurance*, September 2003, pp. 549–561.

[9] W. Kip Viscusi and Joseph E. Aldy, "The value of a statistical life: a critical review of market estimates throughout the world," *Journal of Risk and Uncertainty*, August 2003, pp. 5–76.

[10] "Guidance on treatment of the economic value of a statistical life" (U.S. Department of Transportation, May 6, 2013), http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life.

[11] Thomas J. Kniesner, W. Kip Viscusi, Christopher Woock, and James P. Ziliak, "The value of a statistical life: evidence from panel data," *Review of Economics and Statistics*, February 2012, pp. 74–87.

[12] See "Guidance on treatment."

[13] Thomas J. Kniesner, W. Kip Viscusi, and James P. Ziliak, "Willingness to accept equals willingness to pay for labor market estimates of the value of statistical life," IZA Discussion Paper No. 6816 (Bonn, Germany: Forschungsinstitut zur Zukunft der Arbeit (Institute for the Study of Labor), August 2012), to appear in the *Journal of Risk and Uncertainty* (forthcoming, 2014).

[14] W. Kip Viscusi and Joseph E. Aldy, "Labor market estimates of the senior discount for the value of statistical life," *Journal of Environmental Economics and Management*, May 2007, pp. 377–392.

[15] This pattern is borne out in Viscusi and Aldy, "Labor market estimates"; Joseph E. Aldy and W. Kip Viscusi, "Adjusting the value of a statistical life for age and cohort effects," *Review of Economics and Statistics*, August 2008, pp. 573–581; and W. Kip Viscusi and Joni Hersch, "The mortality cost to smokers," *Journal of Health Economics*, July 2008, pp. 943–958. Each of these articles estimates an inverted-U-shaped relationship such that the initial increasing portion is steeper than the decline in the VSL with age.

[16] Thomas J. Kniesner, W. Kip Viscusi, and James P. Ziliak, "Life-cycle consumption and the age-adjusted value of life," *Contributions to Economic Analysis & Policy*, vol. 5, no. 1, 2006, pp. 1–34.

[17] Aldy and Viscusi, "Adjusting the value of a statistical life."

[18] Joni Hersch and W. Kip Viscusi, "Immigrant status and the value of statistical life," *Journal of Human Resources*, Summer 2010, pp. 749–771.

[19] See W. Kip Viscusi, "Racial differences in labor market values of a statistical life," *Journal of Risk and Uncertainty*, December 2003, pp. 239–256; and John D. Leeth and John Ruser, "Compensating wage differentials for fatal and nonfatal injury risk by gender and race," *Journal of Risk and Uncertainty*, December 2003, pp. 257–277.

[20] See Scott Richardson, John Ruser, and Peggy Suarez, "Appendix D: Hispanic workers in the United States: an analysis of employment distributions, fatal occupational injuries, and non-fatal occupational injuries and illnesses," in Committee on Communicating Occupational Safety and Health Information to Spanish-speaking Workers; Committee on Earth Resources; Board on Earth Sciences and Resources (BESR); Division on Earth and Life Studies (DELS); and National Research Council, *Safety is seguridad: a workshop summary*, pp. 43–82 (Washington: National Academies Press, 2003); and Katherine Loh and Scott Richardson, "Foreign-born workers: trends in fatal occupational injuries, 1996–2001," *Monthly Labor Review*, June 2004, pp. 42–53.

[21] See Viscusi and Aldy, "The value of a statistical life."

[22] See Thomas J. Kniesner, W. Kip Viscusi, and James P. Ziliak, "Policy relevant heterogeneity in the value of statistical life: new evidence from panel data quantile regressions," *Journal of Risk and Uncertainty*, February 2010, pp. 15–31; and Mary F. Evans

and Georg Schaur, "A quantile estimation approach to identify income and age variation in the value of a statistical life," *Journal of Environmental Economics and Management*, May 2010, pp. 260–270.

[23] In this regard, the U.S. Department of Transportation memo titled "Guidance on treatment of the economic value of a statistical life" (see note 10) cites both the meta-analytical results and the more recent quantile evidence and has proposed an intermediate income elasticity of 1.0.

[24] Joni Hersch, "Compensating differentials for gender-specific job injury risks," *American Economic Review*, June 1998, pp. 598–607.

[25] Thus, even when the fatality rate coefficients in a log wage equation are similar for men and women, as they are in Viscusi and Hersch's "The mortality cost to smokers," the lower wage rate for women leads to a lower estimated VSL.

[26] Carol R. Scotton and Laura O. Taylor, "Valuing risk reductions: incorporating risk heterogeneity into a revealed preference framework," *Resource and Energy Economics*, May 2011, pp. 381–397.

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