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Jason F. Shogren

University of Wyoming, efchair@uwyo.edu

T. Stamland

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# Skill and the Value of Life

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Jason F. Shogren and Tommy Stamland

*University of Wyoming*

The value of statistical life (VSL) can be inferred through real-world wage–fatality risk trade-offs made across different occupations. This paper shows that the VSL based on the wage-risk trade-off tends to be biased upward if it does not account for the diversity of workers' unobservable skill to cope privately with job risk. This upward bias arises because the highest required wage differential among the workers is divided by their average risk across the population.

## I. Introduction

Twenty-five years ago Thaler and Rosen (1976, p. 265) observed that a “lively controversy has centered in recent years on the methodology for evaluating life-saving on government projects and in public policy.” Their statement still holds today. The value of lives saved or, more commonly, the value of statistical life (VSL) is by far the largest category of benefits used to justify new federal environmental, health, and safety rules (Viscusi 1993). A prominent example is the U.S. Environmental Protection Agency's application of the VSL to justify the 2000 diesel sulfur rule. Here the VSL accounted for nearly 90 percent of the estimated annual total benefits from improved air quality, \$62.6 billion out of \$70.4 billion (U.S. Environmental Protection Agency 2000). The political economy of the VSL is unambiguous: the larger the VSL, the

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more likely the benefits will justify the costs of any new regulation aimed at protecting health and safety.

In fact, the standard logic in the valuation literature is that the VSL is, if anything, biased downward. Hwang, Reed, and Hubbard (1992), for instance, make the case that the VSL as inferred through real-world wage-risk trade-offs made across different occupations and industries has a downward bias since an econometrician only partially observes the workers' characteristics and therefore underestimates the wage differential needed to compensate for a job disamenity such as fatality risk.

This paper shows, however, that existing estimates of VSL based on wage-risk trade-offs are likely to be biased upward once one accounts for worker heterogeneity in both *risk preference* and *skill*—the personal ability to reduce risk of death or injury (Ehrlich and Becker 1972; Shogren and Crocker 1991).<sup>1</sup> Relative to workers in less risky occupations, a worker who chooses a risky occupation reveals himself to be more tolerant to risk or more skilled in personal risk reduction or both. This means that the selection of occupation is unlikely to reveal perfectly both personal characteristics (Stamland 1999, 2001). The highest required wage differential—that of the marginal worker who tends to be low-skill/high-risk—is divided by the workers' average risk, which causes an upward bias in the VSL.

## II. The Model

Consider workers who differ in two *unobservable* respects: they are unequally skilled and they disagree on the value of life. Different skill levels imply that workers do not face the same probability of a fatal accident in the same job. Risk is endogenous. Different risk preferences mean that they have different trade-offs between job wages and the on-the-job risk of a fatal accident. In the safe job, all workers face a probability  $p \geq 0$  of a fatal accident. In the dangerous job, the likelihood of an accident decreases in the worker's skill. The safe job pays compensation  $w_s$  and the dangerous job pays  $w_d$ . The difference in the wages,  $w_d - w_s$ , is endogenously given, so the dangerous job will attract a given number of workers. The wage differential is set so that it is just sufficient to compensate the worker in the dangerous job who requires the highest compensation for the additional risk.

Assume that  $T$  workers toil in the dangerous job in the labor market equilibrium. Each has his own value of life,  $VOL_t > 0$ , and his own risk associated with the dangerous job,  $q_t \geq p$  for all  $t \in \{1, 2, \dots, T\}$ . Assume

<sup>1</sup> The workers in a job need not be equally skilled or equally tolerant to risk because of differences in self-protection, self-insurance, job stickiness, switching costs, irreversibility, imperfect mobility across occupations, life cycle in skills, experience, education, and safety (see, e.g., Shapiro and Stiglitz 1984).

that there is a type  $t$  such that  $q_t > p$ . We denote the workers' utility function by  $u(t, P, W)$ , where  $t$  denotes the worker's type,  $P \in \{p, q\}$  is the worker's fatality risk in a job, and  $W \in \{w_s, w_d\}$  is the worker's wage. For now, assume that the worker's utility function takes the simple form  $u(t, P, W) = W - P \cdot \text{VOL}_t$ , where  $\text{VOL}_t$  is the monetary equivalent of type  $t$ 's opportunity cost associated with premature death in the current period; that is,  $\text{VOL}_t$  is type  $t$ 's value of life.

Since there are  $T$  workers in the dangerous job in equilibrium, the wage differential is determined by

$$w_d = w_s + \max_{t \in \{1, 2, \dots, T\}} \{(q_t - p)\text{VOL}_t\}.$$

The overall probability that a randomly selected worker will have a fatal accident in the safe job is  $P_s \equiv p$  because all types of workers have the same risk,  $p$ , in this job. The corresponding probability in the dangerous job is  $P_d = (1/T) \sum_{t=1}^T q_t \equiv \bar{q}$ .

If the wages and the statistical probabilities of an accident are used to infer the value of a statistical life by taking the ratio of the wage differential to the risk differential,  $\text{VSL} = (w_d - w_s)/(P_d - P_s)$ , we have

$$\text{VSL} = \frac{\max_{t \in \{1, 2, \dots, T\}} \{(q_t - p)\text{VOL}_t\}}{\bar{q} - p} = \frac{(q_\tau - p)\text{VOL}_\tau}{\bar{q} - p},$$

where  $\tau$  denotes the type that maximizes  $(q_t - p)\text{VOL}_t$  with respect to  $t$  (i.e.,  $\tau$  is the marginal worker in the dangerous job). Define  $\overline{\text{VOL}} \equiv (1/T) \sum_{t=1}^T \text{VOL}_t$ . We now have

$$\frac{\overline{\text{VOL}}}{\text{VSL}} = \frac{(\bar{q} - p)\overline{\text{VOL}}}{(q_\tau - p)\text{VOL}_\tau}.$$

By the definition of  $\tau$ , this means that VSL overestimates the average value of life unless the following condition holds.

CONDITION 1.  $(q_t - p)\text{VOL}_t \leq (\bar{q} - p)\overline{\text{VOL}}$  for all  $t$ .

For this condition to hold, there must be a strong inverse relationship between  $q_t - p$  and  $\text{VOL}_t$ . This relationship need not be as strong as having perfect negative correlation or a perfect inverse relationship. It must be the case, however, that whenever one variable is a given percentage *above* its mean, the other variable must be at least the same percentage *below* its mean. While possible, it is unlikely that there will be such an inverse relationship between the two variables among the workers in the dangerous job, particularly if the number of workers in the dangerous job is large. The following proposition summarizes this result.

PROPOSITION 1. Unless condition 1 holds, the VSL overestimates the average value of life of the workers in the dangerous job.

Consider an example with two worker types. Assume that  $VOL_t = VOL$  (a constant) for all  $t$ ,  $N$  workers have risk  $q_t = q$ , and the rest have risk  $q_t = p$ . We have  $w_d = w_s + (q - p)VOL$  and  $P_d = p + (q - p)(N/T)$ , which implies  $VSL = (T/N)VOL$ . The fewer low-skilled/high-risk workers,  $N$ , who work in the dangerous job, the greater the VSL overestimates the value of reduced mortality risk. If  $VOL = \$1$  million, for instance, this yields a VSL of  $\$6$  million when one-sixth of the workers are low-skilled.

Consider now the special cases in which only one characteristic varies. (1) Suppose that  $VOL_t = VOL$  (a constant) for all  $t$  and that  $q_t$  varies among the workers in the dangerous job. Define  $q^* = \max_{t \in \{1, 2, \dots, T\}} q_t$ . We have  $w_d = w_s + q^*VOL$  such that  $VSL/VOL = q^*/\bar{q} > 1$ . (2) Suppose that  $q_t = q$  (a constant) for all  $t$  and  $VOL_t$  varies among the workers in the dangerous job. Define  $VOL^* = \max_{t \in \{1, 2, \dots, T\}} VOL_t$ . We have  $w_d = w_s + qVOL^*$ , and so  $VSL/\overline{VOL} = VOL^*/\overline{VOL} > 1$ . The VSL is always biased if only one of the characteristics—risk or the value of life—varies across the workers. Both characteristics must vary in an inverse relationship, or both characteristics must be constant, for the bias to disappear.

For robustness, consider the more general case in which worker utility,  $u(t, P, W)$ , is any continuous function in  $(p, w)$  that satisfies the following assumptions.

ASSUMPTION 1. If  $q > p$ , then  $u(t, p, W) > u(t, q, W)$  for all  $t, W$ .

ASSUMPTION 2. If  $w' > w$ , then  $u(t, P, w') > u(t, P, w)$  for all  $t, P$ .

The following proposition says that generalizing the model does not necessarily weaken the key result that the VSL tends to be upwardly biased when workers are heterogeneous in skill and risk preferences.<sup>2</sup>

PROPOSITION 2. With general utility functions, using the VSL as an estimate of a person's value of reduced mortality risk always involves a positive expected percentage overstatement of the average value of life of the workers in the dangerous job.

*Proof.* See the Appendix.

### III. Concluding Remarks

The value of statistical life based on wage-risk trade-offs is likely to be biased upward if the highest required wage differential among the workers is divided by their average risk across the population. One can show that this tendency toward an upward bias in the VSL holds even if workers self-select their job on the basis of their value of life and skill,

<sup>2</sup> Note that proposition 2 states that  $E[VSL/VOL_t] > 1$ . This does not imply that  $VSL > E[VOL_t]$ . There are instances in which VSL underestimates  $E[VOL_t]$ , but the tendency is toward overestimation.

or if the VSL is compared to the population average value of life (Shogren and Stamland 2001). The results support those who argue that the VSL estimates used in federal decision making probably overestimate the benefits of new major regulatory decisions (see, e.g., Lutter and Belzer 1999; U.S. Environmental Protection Agency 1999). In addition, if workers more easily self-select within an industry than across industries, this could explain why occupational data lead to smaller VSL estimates than industrial data.

Finally, accounting for individual heterogeneity across preferences and skill requires more sophisticated econometric techniques and richer data sets. One can use a general method of moments (GMM) framework that combines moment conditions generated by individual behavior with moment conditions from other data sources such as survey data or medical evaluations to get a handle on unobserved variables (Shogren and Stamland 2002). This GMM method yields an unbiased VSL estimate.

## Appendix

### Proof of Proposition 2

Define  $W_d(t, q_p, p, w_s)$  as the solution for  $W$  in the equation  $u(t, q_p, W) = u(t, p, w_s)$ , in which  $t, q_p, p$ , and  $w_s$  are taken as given. It follows from continuity and assumptions 1 and 2 that  $W_d(t, q_p, p, w_s)$  is well defined and unique. Furthermore, since we maintain the assumption that  $q_t \geq p$  (where strict inequality holds for at least one type,  $t$ ), we have  $W_d(t, q_p, p, w_s) \geq w_s$  for all  $t$ . In equilibrium, we have  $w_d = \max_{t \in \{1, 2, \dots, T\}} W_d(t, q_p, p, w_s)$ , where workers 1, ...,  $T$  take the dangerous job. Define

$$\text{VOL}_t \equiv \frac{W_d(t, q_p, p, w_s) - w_s}{q_t - p}.$$

We now have

$$\frac{\text{VSL}}{\text{VOL}_t} = \frac{q_t - p W_d(\tau, q_\tau, p, w_s) - w_s}{\bar{q} - p W_d(t, q_p, p, w_s) - w_s},$$

where, as before,  $\tau$  is the marginal worker who sets the wage, which implies that the second fraction on the right-hand side is always larger than, or equal to, one. Since we assume that the workers are heterogeneous (i.e., they do not all demand the same wage), it follows that the fraction is strictly larger than one for some  $t$ , and hence we have that

$$E \left[ \frac{\text{VSL}}{\text{VOL}_t} \right] > \frac{\bar{q} - p}{\bar{q} - p} = 1.$$

Q.E.D.

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