Cost-benefit analysis: value of statistical life

Definition

Definition – The value of statistical life (VSL) is a tradeoff value between mortality risk and money. VSL indicates the dollar amount the population is willing to pay in order to reduce risk of death, as well as, the marginal value of improving safety.

Source: https://tinyurl.com/ya8nattg

Intuition

Intuition – More hazardous jobs are less desirable due to higher chances of injuries and death. Therefore, riskier jobs require higher wages so that workers will work. But should society use this information to decide the value of a life? And how much wage increase is enough to offset the fatal risks? VSL attempts to estimate the risks to life and the value of life, in complex situations. VSL is a crucial policy instrument to evaluate safety, health and environmental regulations.

Mathematical / Technical

- The VSL has historically been calculated by setting the value of an expected fatality equal to the value of income loss and medical costs that death involves.
- Suppose that an agent can take an action that affects changes wealth, denoted Δw and thus changes their fatality rate by Δp. Then, the VSL for the tradeoff from the mortality risk is the following:

$$VSL = \frac{\Delta w}{\Delta p} \approx \frac{dw}{dp}$$

- The Δ form is for a discrete change; the latter form is the derivative and measures an infinitesimal change.
- The individual's expected utility is as follows:

$$E[U] = p * (U(w(p)|dead) + (1-p) * (U(w(p)|survive),$$

where $U(w(p))$ is the utility of a given wealth, which is a function of p, the probability of death.

- The expected utility is the weighted sums of the utilities when the individual dies and survives, written in short-hand as $E[U] = p * U_d + (1-p) * U_s$.
- Then, the agent maximizes expected utility, by choosing p, and thus implicitly choosing w:

$$max\ E[U] \rightarrow \frac{dE[U(w(p))]}{dp} = \emptyset$$

$$\frac{dU}{dp} = p * U_d' * \frac{dw}{dp} + U_d + U_s' \frac{dw}{dp} - p * U_s' \frac{dw}{dp} - U_s = \emptyset$$

- Solve for $\frac{dw}{dp}$ to get individual VSL, as defined above:

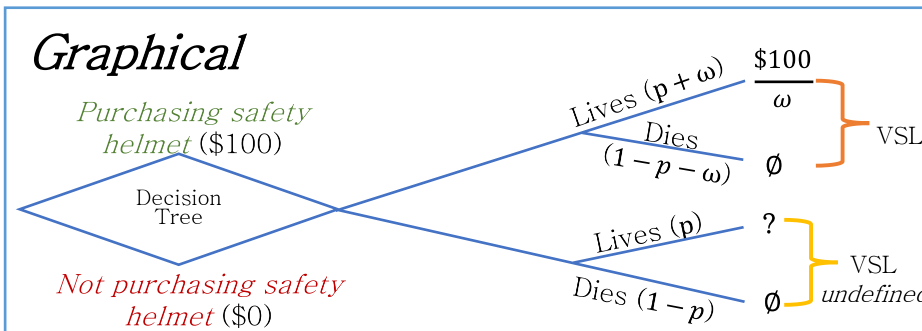
$$\frac{dw}{dp} = \frac{U_s - U_d}{p * U_d' + (1-p) * U_s'} = VSL$$

- Note: VSL is strictly positive due to these conditions:
  - *(i)* $U_s(w) > U_d(w)$
  - *(ii)* $U_d'(w) > U_s'(w) \geq 0$
  - *(iii)* $U_s''(w) \leq 0$ & $u''_d(w) \leq 0$
- Utility of survival is strictly greater than the utility if dead. Also, utility is increasing, such that the marginal utility if dead is strictly greater than the marginal utility of survival. The third condition indicates the utility increases at a decreasing rate.

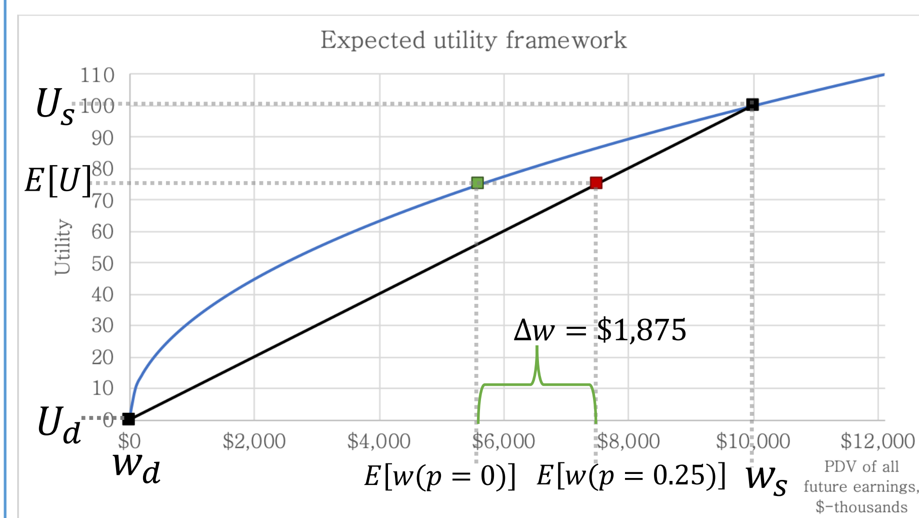
General example, graphical approach, with high & low risk:

$$VSL = \frac{\Delta w}{\Delta p} = \frac{E[w(p_{high})] - E[w(p_{low})]}{p_{high} - p_{low}}$$

Graphical



A decision to purchase a safety helmet. The upper branch is the choice to spend $100 increasing the survival probability by ω. Otherwise, **not** spending $100 and survival rate is p. VSL is the willingness to pay divided by ω.



The Δw is the difference of expected wealth with risk versus without, Δp is $0.25 - 0 = 0.25 \rightarrow VSL = \$7.5$ *million.*

Real-world aspects

Real-world aspects – The average VSL for the US population is between \$4 and \$10 million. A meta-analysis of 35 studies for 20 countries gives an average global value of just over \$3 million, with data from years 1985 to 2009.[a] The most standard VSL methodology is a wage-risk study, which calculates the wage premium for the workers in more hazardous work environment – a revealed preference. Stated preference methods can be used, when no clear markets for the type of risk reduction of interest exists.[b] Nonetheless, cost-benefit analysis of VSL estimates still faces many problems in the real world. For instance, a difficult complication arises when the benefits from risk reduction are paid for by the people who are not directly receiving the benefits. As non-beneficiaries, these people may not be as willing to pay for the risk reduction, and thus, reflect a value far off from a reasonable VSL estimate.[c]

Sources: [a] https://tinyurl.com/zyhcavk, [b] https://tinyurl.com/qlz4h8x, [c] Orley A. (2006) Economic Journal

Practice questions

1. Suppose that the average annual workplace mortality rate in the US is around 3 deaths per 100,000 workers. If each individual is willing to pay \$100 to decrease this to 2 deaths per 100,000 workers per year, how much is the VSL?
2. Wage premium is calculated by multiplying the value of statistical life with an increased probability of mortality in workplace. Given that the wage premium is \$500 for 0.01% of increase in mortality rate, calculate the VSL.
3. Assume that the current speed limit is 55 mph. Raising the speed limit by 1 mph would allow the total time saved by the drivers to be 15,000 hours. However, the fatality rate would also increase by 10%. Given that the VSL is \$5 million and that the value of time is \$25 per hour (based on average hourly wage), how much should the speed limit be changed by to reach optimal speed limit?
4. Explain why government needs accurate estimates of VSL to inform public policies (the tradeoffs) for the recent pandemic, COVID-19.

Numerical solutions: **1.** $VSL = \$10$ million 2. $VSL = \$5$ million **3.** \$375,000 saved/mph, 13.3 mph, $speed^* = 68.3$ mph.