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Publication Date

1979-08-01

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economics
Working Paper No. 113

Working Paper No. ¹¹³ 120

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In a recent paper, Blomquist (1979) presented an ingenious method for estimating the monetary worth to an individual of a small change in the probability of surviving based on people's observed choices to wear an automobile seat belt. The "value of life" is found to be about \$370,000 in 1978 dollars, which is fairly similar to the estimates obtained by Thaler and Rosen (1975) and others from an analysis of job choice data. This estimate is open to the objection, which Blomquist recognizes, that the social value of lifesaving activity should not necessarily be based on the private willingnesses to pay as inferred from individuals' choices among risky activities. While accepting Blomquist's basic insight that the private willingness to pay for survival can be inferred from data on individual choice behavior, I will argue that his particular method of measuring this willingness to pay is flawed. He employs two separate models of individual choice behavior, one for his empirical model of seat-belt usage and the other for interpreting the coefficients of the empirical model. Since the two models are not mutually consistent, his estimate of the value of

life is erroneous. After elaborating this argument, I will provide a brief description of an empirical choice model, derived from an underlying utility maximization model, which does lead to a consistent monetary measure of the value of a change in survival probability.

Blomquist starts with a theoretical model of the choice of lifesaving activity which, when slightly simplified, involves the maximization of a welfare function containing the following variables: E , the present value of the individual's labor earnings; A , the present value of his nonlabor income; S , the level of lifesaving activity; $P(S)$, the probability of surviving, as a function of the chosen level of lifesaving activity; q , the cost per unit of lifesaving activity; $R(S)$, the probability of nonfatal injury, as a function of lifesaving activity; and I , the present value of the morbidity costs associated with nonfatal injury. The welfare function has the form

$$v = v [E + A - qS - R(S)I, P(S), S]. \quad (1)$$

The function has three arguments. The first is the individual's present worth, net of illness, and lifesaving expenses; the second is his probability of staying alive; and the third is the actual amount of lifesaving activity. The last argument is included in order to allow for "a disutility (it could be utility) of life-saving activity over and above the resource cost of life-saving activity."¹ The partial derivatives of $v(\cdot)$ will be denoted v_i , $i = 1, 2, 3$. It is presumed that $v_1 > 0$, $v_2 > 0$, and $v_3 > (<) 0$ if a disutility (utility) is attached to the lifesaving activity.

In Blomquist's theoretical analysis the individual selects that value of S which maximizes (1). The first-order condition can be written as

$$(v_2 P' - v_1 R' I) - (v_1 q - v_3) = 0$$

where P' and R' are the first derivatives of $P(S)$ and $R(S)$, respectively. The first term in brackets is the marginal benefit of lifesaving activity, and the second term in brackets is the marginal cost; both are measured in utility units. The condition can be rewritten as

$$[(v_2/v_1) P' - R'I] - [q - (v_3/v_1)] = 0.$$

The two terms in square brackets are, respectively, the marginal benefit and the marginal cost of lifesaving activity measured in money. The ratio (v_2/v_1) is the marginal value of life---i.e., the monetary worth of a unit change in the probability of survival. The ratio (v_3/v_1) is the monetary worth of the marginal disutility cost of lifesaving activity. In his empirical analysis Blomquist seeks to measure these two expressions from data on seat-belt usage. In this context the choice variable, S , is limited to two levels: the individual uses seat belts all of the time ($S = 1$, say) or he uses them none of the time ($S = 0$).² The theoretical utility model (1) can be easily adapted to a binary choice setting. Let Δv be the utility gain from always wearing seat belts over never wearing them

$$\Delta v = v [E + A - q - R(1)I, P(1), 1] - v [E + A - R(0)I, P(0), 0].$$

Writing $\Delta v = (dv/dS) \cdot \Delta S$, and setting $\Delta S = 1$, one finds that Δv is given by

$$\Delta v = (v_2 \Delta P - v_1 \Delta R I) - (v_1 q - v_3) \quad (2)$$

or

$$\Delta v/v_1 = [(v_2/v_1) \Delta P - \Delta R \cdot I] - [q - (v_3/v_1)], \quad (3)$$

where ΔP and ΔR are the changes in the probability of being killed in an accident and the probability of incurring a nonfatal injury, respectively, as a result of always wearing seat belts.

For his empirical analysis of data on seat-belt usage, Blomquist employs the probit model, which is based on a choice index z , given by

$$z = \sum_1^m \beta_j x_j + \eta,$$

where the β_j are fixed parameters, the x_j are variables such as the driver's labor wealth, nonlabor income, education, age, wage rate, marital status, etc., and η is a random term for unobservable differences among individuals (including differences in preferences) which is normally distributed with $E(\eta) = 0$ and $E(\eta^2) = \sigma^2$. If $z > 0$, the individual always wears seat belts ($S = 1$); if $z \leq 0$, he never wears them ($S = 0$). Accordingly, for an individual with characteristics x_j the probability that he always chooses to wear seat belts is given by $[1 - \Phi^*(-\sum \beta_j x_j / \sigma)] = \Phi^*(\sum \beta_j x_j / \sigma)$, where $\Phi^*(\cdot)$ is the standard normal cumulative distribution function. This probability can also be written as $\Phi^*(\sum \beta_j^* x_j)$, where $\beta_j^* = \beta_j / \sigma$. From the data one can only estimate β_j^* — β_j and σ are not separately identifiable. The probit estimates are denoted $\hat{\beta}_j^*$.

Blomquist equates the monetary worth of the net benefit of seat-belt use from the theoretical choice model, $\Delta v / v_1$, with the nonstochastic component of the choice index in the empirical probit model, z , and uses this equation to obtain empirical estimates of σ , (v_2 / v_1) , and (v_3 / v_1) . To estimate σ he assumes that the money cost of using a seat belt in the theoretical choice model, q , may be written $q = awt$, where t is the time consumed in putting on seat belts, w is the wage rate, and a is a factor which converts the wage rate into the money value of time when traveling; this relation can also be written $q = \Theta w$, where $\Theta = at$. In the empirical probit model one of the x_j variables is the wage rate, w . Denote the corresponding slope coefficient β_w and let $\beta_w^* = \beta_w / \sigma$. Thus, the choice index can be written as

$$z = \beta_w w + \sum_{j \neq w} \beta_j x_j + \eta. \quad (4)$$

Since he equates z with $\Delta v/v_1$, Blomquist identifies q , which is one component of $\Delta v/v_1$, with the term $\beta_w w$ in (4); hence, $\theta = \beta_w = \sigma \beta_w^*$. Using the probit estimate, $\hat{\beta}_w^*$, and exogenous information on θ , he obtains the estimate $\hat{\theta} = \theta/\hat{\beta}_w^*$.³ Next, consider a driver with the average characteristics of the sample, \bar{x}_j . His standardized choice index score, as predicted by the empirical probit model, is $\bar{z}^* = \sum \hat{\beta}_j^* \bar{x}_j$, and his predicted probability of choosing to wear seat belts is $\Phi^*(\bar{z}^*)$. From the theoretical choice model, the monetary worth of his net benefit from using seat belts is

$$\frac{\overline{\Delta v}}{v_1} = \left[\left(\frac{\overline{v_2}}{v_1} \right) \cdot \overline{\Delta P} - \overline{\Delta R} \bar{I} \right] - \left[\theta \bar{w} - \left(\frac{\overline{v_3}}{v_1} \right) \right], \quad (5)$$

where the bar over each term indicates its average value. Let \dot{z}^* be the quantity such that $\Phi^*(\dot{z}^*) = .23$, the actual proportion of drivers in the sample who always wear seat belts. Blomquist equates \dot{z}^* with $\hat{\sigma}^{-1}$ times the right-hand side of (5).⁴ This yields an equation in two unknowns, $(\overline{v_2}/v_1)$ and $(\overline{v_3}/v_1)$, since the values of the other terms-- $\hat{\sigma}$, \dot{z}^* , θ , \bar{w} , $\overline{\Delta P}$, $\overline{\Delta R}$, and \bar{I} --are all known. Finally, suppose that θ and, hence, q were zero and also that there was no disutility associated with wearing seat belts ($v_3 = 0$). The cost of wearing seat belts--i.e., the second term in square brackets in (5)--would then be zero. In that case, Blomquist argues, the probability of the average driver wearing seat belts would be virtually unity--say, 0.99. Blomquist finds that value \ddot{z}^* such that $\Phi^*(\ddot{z}^*) = .99$, and equates this with $\hat{\sigma}^{-1}$ times the first term in square brackets on the right-hand side of (5). This provides a second equation which, together with the first, can be solved for $(\overline{v_2}/v_1)$, the average driver's marginal value of life, and $(\overline{v_3}/v_1)$, the average driver's disutility of wearing seat belts.

The key to Blomquist's analysis is his equation of the nonstochastic component of z with $\Delta v/v_1$. However, a comparison of the right-hand sides of (3)

and (4) shows that this is not legitimate; since each equation contains some variables not appearing in the other, they clearly constitute different utility models. For example, if the true utility model is (1), the right-hand side of (4) should include such terms as ΔP and $\Delta R \cdot I$, which are missing from Blomquist's empirical model. An empirical choice model which does yield estimates of the value of life and the disutility cost of wearing seat belts that are consistent with the utility model (1) can be developed as follows. Let the individual's welfare function be $u(S) = v(S) + \varepsilon(S)$ where $v(\cdot)$ is a nonstochastic function of attributes of seat-belt usage and characteristics of the individual, and $\varepsilon(\cdot)$ is a stochastic term reflecting individual differences in tastes or unobserved attributes. Then $z \equiv \Delta u = v(1) - v(0) + \eta$, where $\eta \equiv \varepsilon(1) - \varepsilon(0)$; and, as before, $S = 1$ if and only if $\Delta u > 0$. In order to proceed it is necessary to impose further restrictions on $v(\cdot)$ beyond those implied in (1), such as additive separability. Suppose, specifically, that when $S = 1$

$$v(1) = v_1^1 \cdot [R(1) I - \Theta w] + v_2^1 \cdot [P(1)] + v_3^1, \quad (6a)$$

where I follow Blomquist in assuming that $q = \Theta w$, and when $S = 0$

$$v(0) = v_1^0 \cdot [R(0) I] + v_2^0 \cdot [P(0)], \quad (6b)$$

where v_1^0 , v_1^1 , v_2^0 , v_2^1 , v_3^1 , and Θ are constants to be estimated.⁵ Then

$$\begin{aligned} z = & v_1^1 \cdot R(1)I - v_1^0 \cdot R(0)I - (v_1^1 \Theta)w \\ & + v_2^1 \cdot P(1) - v_2^0 P(0) + v_3^1 + \eta \end{aligned} \quad (7)$$

or, if $v_i^1 = v_i^0 = v_i$, $i = 1$ and 2

$$z = v_1 \cdot \Delta R \cdot I - (v_1 \ominus)w + v_2 \Delta P + v_3 + \eta. \quad (8)$$

Either (7) or (8) can form the basis for an empirical probit or logit model.⁶ In the terminology of Domencich and McFadden (1975, p. 54), the formulation in (7) is a nongeneric weight model, while that in (8) is a generic weight model. In both cases the constant term in the probit equation, v_3 , measures the disutility cost of wearing seat belts. It should be noted that the coefficients v_1^j and v_2^j , $j = 0$ and 1 , cannot be estimated if there is no variation in $P(1)$, $P(0)$, $R(1)$, and $R(0)$ across the sample.

One can introduce net worth explicitly into the empirical choice model in at least three ways: (i) Let $Y(1) = A + E - R(1) \cdot I$ and $Y(0) = A + E - R(0) \cdot I$, and substitute $Y(1)$ and $Y(0)$ for $R(1) \cdot I$ and $R(0) \cdot I$ in (7).⁷ (ii) Let $v_1^i = v_1^i (A + E)$, $i = 0, 1$; for example, assume that $v_1^i = \gamma^i \exp[-(A + E)]$, where γ^1 and γ^0 are coefficients to be estimated, and substitute in (7) or (8). (iii) Add a term $v_4^1 \cdot (A + E)$ to (6a) and a term $v_4^0 \cdot (A + E)$ to (6b), which leads to the addition of a term $(v_4^1 - v_4^0) \cdot (A + E)$ to (7) or (8); in this case some normalization is required, such as $v_4^0 = 0$ (i.e., v_4^1 measures the differential effect of net worth on the utility level when seat belts are worn). Other socioeconomic variables, such as age or sex, can be incorporated along the lines of (ii) or (iii).

Within this framework, one can derive from the estimates of the coefficients of (7) or (8) an estimate of a , the conversion factor for the value of travel time and of v_3 , the disutility cost of wearing seat belts. One can also obtain an estimate of the monetary worth to the driver of a change in the probability of surviving. This must be defined with some care. Suppose that net worth has been incorporated into the empirical choice model along the lines suggested above. Denote the fitted utility functions corresponding to

(6a,b), $\hat{v} [A + E, P(1)]$ and $\hat{v} [A + E, P(0)]$, and the corresponding stochastic welfare functions, $\hat{u} [A + E, P(1)] = \hat{v} [A + E, P(1)] + \epsilon(1)$ and $\hat{u} [A + E, P(0)] = \hat{v} [A + E, P(0)] + \epsilon(0)$. Consider a project which changes the probability of surviving when one always wears seat belts from $P(1)$ to $P(1)'$. One may be tempted to evaluate the project by the monetary quantity C such that $E \{ \hat{u} [A + E - C, P(1)'] \} = E \{ \hat{u} [A + E, P(1)] \}$. However, this presumes that the individual will choose to wear a seat belt in both cases. A more appropriate measure is based on \hat{u}^{\max} , defined by

$$\hat{u}^{\max} [A + E, P(1), P(0)] = \text{maximum} \{ \hat{u} [A + E, P(1)], \hat{u} [A + E, P(0)] \}.$$

Let $T [A + E, P(1), P(0)] = E [\hat{u}^{\max}]$. This is the expected utility of an individual with net worth $(A + E)$ who acts optimally in deciding whether to use seat belts and faces survival probabilities of $P(1)$ and $P(0)$. A monetary measure of the value of the project is the quantity C defined by $T [A + E - C, P(1)', P(0)] = T [A + E, P(1), P(0)]$.⁸ In order to construct this welfare measure it is preferable to apply an empirical logit model, rather than a probit model, to (7) or (8). In the probit case the formula for $T [A + E, P(1), P(0)]$ is fairly cumbersome, since this is the mean of the maximum of two nonidentically distributed normal variates.⁹ In the logit case it can be shown that $T = \ln \delta + 0.5722 \dots$ (Eulers' constant), where $\delta = \exp \{ \hat{v} [A + E, P(1)] \} + \exp \{ \hat{v} [A + E, P(0)] \}$, which leads to a fairly simple expression for C .

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Footnotes

¹There is no specific disutility associated with the probability of nonfatal injury, apart from the resource costs. This is slightly implausible, but it does not affect the thrust of my argument.

²Obviously, these are not the only possibilities. There is a third case-- the individual uses seat belts some of the time but not all of the time. One could analyze this three-way choice empirically with an ordinal-discrete dependent variable model; see, for example, Aitchison and Silvey (1957) or McKelvey and Zavoina (1975).

³An alternative approach would be to equate z with Δv , the net benefit of seat-belt use in utility terms, and to adopt the convention, common in probit analysis, that $\sigma = 1$. The term $v_1 q$ in (2) could be equated with the term β_w in (4); hence, $v_1 \theta = \beta_w^*$ and one obtains the estimate $\hat{v}_1 = \hat{\beta}_w^* / \theta$. By continuing with the rest of Blomquist's analysis, but equating (4) with (2) instead of (3), one would obtain exactly the same estimates of $(\overline{v_2/v_1})$ and $(\overline{v_3/v_1})$.

⁴Note that $\dot{z}^* \neq \bar{z}^*$. Since one is working elsewhere with the fitted probit model, it might be more logical to equate \bar{z}^* with $\hat{\sigma}^{-1}$ times the right-hand side of (5), although this would not greatly alter the numerical estimates of $(\overline{v_2/v_1})$ and $(\overline{v_3/v_1})$.

⁵Although the v_1^j terms are constants, the "state dependent" utility functions $v(0)$ and $v(1)$ need not be linear in RI , w , or P since one could employ transforms of these variables (e.g., the logarithm) on the right-hand side of (6a or 6b). All that is required is that the equation be linear in the transforms.

⁶In the probit model one adopts the convention that $\varepsilon(1)$ and $\varepsilon(0)$ are independent normal variates with zero mean and a common variance of 0.5; hence η is a standard unit normal variate. In the logit model one adopts the convention that $\varepsilon(1)$ and $\varepsilon(0)$ are independent Weibull variables with common parameters (1, 0); in this case η is a logistic variate.

⁷If the restriction that $v_1^1 = v_1^0$ is imposed, as in (8), the term (A + E) would drop out of the empirical estimating equation with this method of incorporating net worth.

⁸This is a compensating-variation type of measure; an equivalent variation measure can also be defined. Moreover, similar measures can also be defined for a project which changes $P(0)$, $R(0)$, $R(1)$, and/or I . These types of welfare measures were originally suggested by Domencich and McFadden (1975, p. 97) and are elaborated in Hanemann (1978, pp. 142-146).

⁹Let $\hat{v}_1 = \hat{v} [A + E, P(1)]$ and $\hat{v}_0 = \hat{v} [A + E, P(0)]$. It can be shown that $T = \hat{v}_1 + \phi^*(\xi) + \xi \cdot \Phi^*(\xi)$, where $\xi = \hat{v}_0 - \hat{v}_1$ and ϕ^* and Φ^* are the standard unit normal density and distribution functions. Since probit and logit coefficient estimates are usually fairly similar in practice, nothing is lost by employing the empirical logit model instead of the probit model.