Price and Value of Time

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Early studies of the value of time seemed to use the terms "value of time" and "price of time" interchangeably to define the value or the shadow price people place on their time. It has been pointed out recently that it may be worthwhile to distinguish between these 2 terms, reserving the term "price" for the amount of money people have to forgo to save 1 unit of time and the term "value" for the amount of money people are willing to pay to save 1 unit of time (2). It has also been alleged that some of the studies claiming to have estimated the value of time have in effect estimated the price of time and that the conventional methods of analysis of binary choice (e.g., discriminant analysis, probit, logit) may be appropriate for the analysis of modal split but are completely inadequate for the estimation of the value of time.

These issues are examined here, and a new method is suggested for the estimation of the value of time. I have not yet applied this method in practice, so I can claim not that it is a better empirical tool but only that it is more comprehensible to someone who has the estimation of the value of time in mind.

The usual way of estimating the value of time in a situation of binary choice is based on the equation (I have intentionally omitted the constant term b_0 from this formulation)

$$X_1 = b_1(P_2 - P_1) + b_2(T_2 - T_1) + e \qquad (1)$$

where X_1 is a dummy variable denoting whether the traveler used mode 1 ($X_1 = 1$) or mode 2 ($X_1 = 0$); P_1 is the money cost involved; T_1 is the elapsed time; and e is the residual in the regression equation. The coefficients b_1 and b_2, obtained by using probit, logit, or discriminant analysis, measure the effect of price and time differentials on the modal choice. The ratio of the coefficients, b_2/b_1, is interpreted as the value of time.

This method has recently come under fire on 2 counts: (a) a statistical one—though b_1 and b_2 may be highly significant (i.e., their random error is relatively small), their ratio may be subject to a large variability; and (b) a conceptual one—the ratio b_2/b_1 is not an estimate of the value but rather the price of time (2). The first of these reservations is an empirical one and calls for new methods of estimation that will reduce the random error of the value of time estimate and increase its reliability. The second is more substantial and calls for a reexamination of the theoretical basis underlying Eq. 1.

Conventional analysis confines the decision of modal choice to 2 measurable characteristics: the money cost of traveling by a given mode P and the opportunity costs of time V(T), where T denotes traveling time. Adhering to this simple model, I ignore for the time being other characteristics of the mode that may affect the traveler's

choice (factors conveniently lumped together as comfort and convenience). If we assume for simplicity that there exist only 2 alternative modes of travel, the traveler's decision criterion is assumed to depend on the generalized cost function Π.

$$\Pi = P + V(T) \tag{2}$$

A traveler prefers mode 1 to mode 2 if the generalized cost function of 1 is less than that of 2,

$$\Pi_1 < \Pi_2 \tag{3}$$

If we assumed that the value a person places on each unit of his time K is the same and independent of the length of his trip

$$V(T) = KT \tag{4}$$

we can rewrite the generalized cost function

$$\Pi = P + KT \tag{5}$$

Mode 1 is preferred if

$$\Pi_2 - \Pi_1 = (P_2 - P_1) + K(T_2 - T_1) > 0 \tag{6}$$

Alternatively, the traveler's decision criteria can be reformulated in terms of the value of time K. A person prefers the faster mode 1 if

$$K > (P_1 - P_2)/(T_2 - T_1) = K^* \tag{7}$$

K^* is the additional amount of money the traveler has to forgo in order to save 1 unit of time, i.e., the price of time. Thus, travelers with a value of time that exceeds the price of time will choose the faster mode, and those with a value of time that is smaller than the price of time prefer the slower one. [If the average value of time varies with T, we could not formulate the decision criterion in these terms. If $V(T_1) = K_1T_1$, a person prefers mode 1 if $P_1 + K_1T_1 < P_2 + K_2T_2$; i.e., if $K_1 > (P_1 - P_2)/(kT_2 - T_1)$, where $k = K_2/K_1$.] For example, if the air fare is \$24 and the train fare is \$12 from New York to Boston and the traveling time is 2 and 4 hours respectively, then everyone with a value of time exceeding \$6 per hour prefers the plane and those with a value of time short of \$6/hour prefer the train, \$6/hour being the price of time.

It is clear from the last example that one needs no data on modal split to compute a price of time. A reliable travel agent providing the data on fares and traveling time by the various modes should suffice. It may be argued that the traveler's conceptions of the price differential and the time savings differ from those of the travel agent, but even then, one does not need information on modal choice to estimate the "perceived" price of time but better data on the person's perceptions about traveling time and costs.

Data on modal choice become important when one tries to estimate the value of time. Observing the modal split of a group of travelers facing the same modal choice who seem to be homogeneous in terms of the value and (perceived) price of time, one would expect the whole group to make the same choice. The observation that different members of the group make different choices indicates that it was apparently wrong to assume that all members are homogeneous with respect to their values or price of time or both. (Another explanation, which I have ruled out, is that there are more than 2 factors affecting the modal-choice decision.)

Let us first assume that there is no error of measurement of the price of time (i.e., there is no error in the estimates of the price differential and the time differential). Intragroup differences in choice, therefore, originate from intragroup differences in the value of time. Let the group's mean value of time be μ; then

$$K = \mu + \epsilon \tag{8}$$

where ϵ is a stochastic term varying from person to person. By Eq. 6 a person prefers the faster mode if

$$(P_2 - P_1) + \mu(T_2 - T_1) > (T_1 - T_2)\epsilon = u \tag{9}$$

The specific assumptions about the distribution of u determine the statistical method used to estimate Eq. 1. If the assumptions hold, then a comparison of Eqs. 1 and 9 indicates that the ratio b_2/b_1 serves as an estimator of the mean value of time μ.

For example, let it be assumed that u has a normal distribution with standard deviation of σ_u.

$$u \sim N(0, \sigma_u) \tag{10}$$

The probability that the traveler uses the faster mode is

$$\begin{aligned} \text{Prob}[X_i = 1] &= \text{prob}\{(u/\sigma_u) < [(P_2 - P_1) + \mu(T_2 - T_1)]/\sigma_u = Z\} \\ &= (2\Pi)^{-1/2} \int_{-\infty}^{Z} \exp(-y^2/2)\, dy \end{aligned} \tag{11}$$

Estimating Eq. 1 by the probit method yields the coefficients of Z; i.e., b_1 is an estimate of $(1/\sigma_u)$, b_2 is an estimate of (μ/σ_u), and the ratio b_2/b_1 is an estimate of μ. There is, however, no way of isolating the other parameters of K, e.g., the standard deviation σ_ϵ. The variability of the stochastic variable u reflects both the variability of K and the variability of the time differential $(T_2 - T_1)$. Thus, the conventional method yields a point estimate of the mean but no additional information of the distribution of the value of time.

There is, however, an alternative method of estimating the value of time based on Eq. 7. Confronted by a price of time of K^*, the person chooses the faster mode if $K > K^*$; i.e., if

$$\mu - K^* > -\epsilon \tag{12}$$

Thus, one should estimate

$$X_i = a_o + a_1 K^* + e \tag{13}$$

where the estimation method depends on the assumed properties of ϵ. If, for example, it is assumed that the intragroup distribution of the value of time is normal

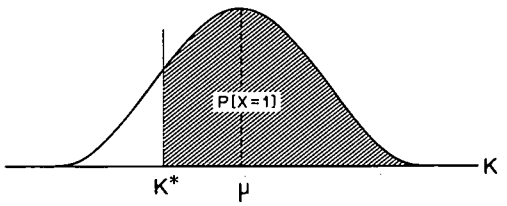
$$\epsilon \sim N(0, \sigma_\epsilon) \tag{14}$$

the probability of choosing the faster mode is (Fig. 1)

$$\begin{aligned} \text{Prob}[X_i = 1] &= \text{prob}[-\epsilon/\sigma < (\mu - K^*)/\sigma_\epsilon = Z^*] \\ &= (2\Pi)^{-1/2} \int_{-\infty}^{Z^*} \exp(-y^2/2)\, dy \end{aligned} \tag{15}$$

The coefficients of Z^* can be obtained by estimating Eq. 13 within each socioeconomic group by the use of the probit method where a_o = est (μ/σ_ϵ) and a_1 = est $(1/\sigma_\epsilon)$. Hence, a_o/a_1 should yield an estimate of the mean value of time μ, and $(1/a_1)$ should yield an estimate of the dispersion of the distribution. Furthermore, if it is assumed that the mean value of time varies systematically with the socioeconomic characteristics of the

Figure 1.



group (say, income, education, age, sex, family composition, purpose of trip) but σ_ϵ is constant, one can introduce this relation directly into Eq. 13. Let $\mu = \alpha Y$, where Y is a vector of characteristics, and α of coefficients, then one can estimate

$$X_t = aY + a_1K^* + e \qquad (16)$$

where $a_1 = \text{est}\ (1/\sigma_\epsilon)$ and $a = \text{est}\ (\alpha/\sigma_\epsilon)$, to obtain estimates of the determinants of the value of time. [An application of this method for the estimation of the value of time of housewives is given in another report (1).]

It seems to me that, if the major purpose of the study is the estimation of the value of time and if intragroup difference in modal choice can be attributed exclusively to differences in the value of time, the new method (Eqs. 13 and 16) provides a more natural framework for the analysis. This conclusion is not much affected if one opts for the alternative explanation, i.e., that the value of time is the same for all the members of the group ($K = \mu$, $\sigma_\epsilon = 0$), but there exist errors in the measurement of the price and time differentials. In this case u and ϵ depend on the errors of measurement and not on the random component of the value of time. If it is assumed that the errors have a normal distribution, u has a normal distribution and one should use Eq. 1 for the estimation of the value of time $K = \mu$. On the other hand, if it is assumed that the error in the measurement of the price of time K^* has a normal distribution, Eq. 13 is preferred. Finally, if one allows for both error in measurement and a random component in K, one cannot separate in the estimate of the standard deviation of the stochastic term obtained through Eqs. 1 and 13 the part that is due to the variability of the value of time and the part that originated from the error of measurement. In the last case one has to be consoled with the estimate of the mean value of time, but one cannot obtain any additional information of the shape of the distribution.

In conclusion, it seems that from a theoretical and methodological point of view the new method has a slight edge over the conventional one. However, the question of which is better cannot be settled on theoretical grounds but depends largely on the empirical evidence. One method may serve as a better prediction of modal split, in the sense that it provides a better fit, but may be an inferior method for the estimation of μ because of the large variability of the ratio of the relevant coefficients. The variability of the price of time as well as the variability and multicollinearity between the price and time differentials should affect the final outcome. At this stage we have to reserve our final judgment until the empirical results are in.

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