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ABSTRACT

Past studies have relied on cross-section patterns of risky behavior to generate value of life estimates. Because numerous problems have been encountered using this approach, the reliability of the estimates has been questioned. It has proven difficult to separate the risk components from the (dis)utility attributes of work or consumption; to avoid selectivity biases; and to disentangle user costs (e.g., for wearing a face mask) from the risk premium paid for accepting risk. To circumvent some of these difficulties, this paper uses a different approach, one which exploits the implicit value of life information that is provided by changing consumption patterns over time brought about by changes in available information about risks. Since data is often available that describes consumption habits before and after health information is announced, it is possible to more reliably estimate the pure effects of risks on behavior, and to generate unbiased distributions of the value of life saving. The case of cigarette consumption over time provides an ideal setting to illustrate this methodology.

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MEASURING THE VALUE OF LIFE FROM CONSUMER REACTIONS TO NEW INFORMATION

by

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I. INTRODUCTION

It is now well accepted that the value of life can in principle be estimated by observing individuals' behavior in accepting life-threatening risks in market transactions. Numerous studies have adopted this approach by comparing either wage or consumption patterns against various measures of risk (e.g., Blomquist 1979; Smith 1976; Thaler and Rosen 1975; or Viscusi 1978).[1/] Though substantial progress has been made in overcoming many measurement and technical problems with value of life estimates, several methodological difficulties remain that hinder attempts to develop more refined and reliable measures of the value of life.

Among these are the problems of self-selection and the difficulties of separating the risk components from the utility attributes of an activity. Coal miners receive wage premiums for (unmeasured) job attributes other than risk. High-rise construction workers are not randomly chosen from the population. For the most part, these problems are inherent in methods that extract value of life estimates from cross section observations on risky activities. It is extremely difficult to measure risk premiums or to avoid selection bias once markets have internalized the presence of unusual risk.

In this paper, an attempt is made to derive value of life estimates that are free from these biases, and to accommodate many of the criticisms that have been made about previous work. As a first step, the study deliberately avoids reliance on existing patterns of risky behavior to generate information on the value of life. Instead, advantage is taken of changing consumption patterns over time brought about by changes in available information about risks.

In particular, consumer reactions to cigarette health information are considered. The analysis is performed over a period in which cigarette smoking changed from being considered relatively safe to being considered quite risky. The well-publicized campaign to inform consumers of the dangers of smoking cigarettes has no serious competing explanation for the dramatic switch toward safer smoking habits over the last 25 years. As such, the risk component of cigarette demand can be more reliably separated from its utility component. Moreover, by viewing snapshots of market behavior over the period of adjustment to the new information, the reactions of a representative population of consumers can be measured.

The approach presented here is designed to go futher than providing an arguably unbiased estimate of the average value of life. An attempt is also made to estimate the distribution of values of life across the population. Critics who have suspected that the variance of values of life held by the population is too large to be represented by average back-of-the-envelope calculations will not be disappointed by the results reported below. For example, consumers who continue to smoke, despite health warnings, are estimated to hold values of life that are less than one-half those held by non-smokers.

Three additional novelties considered below are worth highlighting. First, the paper accounts for product quality adjustments to risks. If risk exposure is partly reduced by a user cost of sorts (e.g., wearing a face mask), observed risk premiums partly represent compensation for accepting remaining risks and partly represent compensation for the user cost. A primary way smokers reacted to risk disclosures has been to switch to cigarettes with less taste (and less nicotine). Reductions in cigarette demand over time are due partly to the life-threatening cost of smoking and partly to a related (voluntary) reduction in the quality of cigarette smoked. By disentangling these effects, it is discovered that approximately one-fourth of the information-related reduction in demand is attributable to the quality effect and that the value of life calculation could have been misstated by as much as 50 percent had this nuance been ignored.

Second, the study evaluates consumer reactions to a health hazard. Compared to, say, highway or occupational accidents, cigarette smoking causes reductions of life in later years with a much higher degree of certainty (as in the development of lung cancer or heart disease after 20-30 years of smoking). As such, individuals' time preference rates and the time pattern of the risk over lifetime become central features in the value of life calculation.

Finally, attention is given to a recurring complaint about value of life studies, that consumer perceptions of risks may differ significantly from scientific measures of risk. Individuals who accept relatively high risks may have relatively low values of life, or they may hold unrealistic perceptions about the magnitude of the risks they face. Using survey data that describe consumer beliefs about the health hazards of smoking, the implications of varied subjective beliefs are systematically considered. In the case of cigarettes, it turns out that these considerations do not alter the conclusions of a model that excludes the issue of subjective beliefs, but their potential for significantly changing the results is aptly demonstrated.

II. A BRIEF OUTLINE OF THE APPROACH

The basic approach used below to measure the value of life can be easily demonstrated with the aid of figure 1. Suppose there are two types of cigarettes and the individual will choose one type or the other. Both sell for the price P_c but one is a high nicotine and high taste (H) cigarette and the other is a low nicotine and therefore low taste (L) cigarette. In figure 1 the underlying demand curves for the two types of cigarettes are shown as HH' and LL'. If an individual is unaware of the health cost of smoking, he naturally chooses the higher taste cigarette because there is no price premium for the additional taste; at price P_c, the individual smokes Q_0 high taste cigarettes per period.

After receiving information about the risks of smoking, the demand curves for high taste and low taste cigarettes fall to reflect the health costs of smoking. In figure 1, these revised demand curves are depicted by the schedules H*H'* and L*L'*. The vertical shifts M_L and M_H in these demand curves reflect the individual's assessment of the health cost of smoking each type of cigarette. Because of the higher "health price" associated with high taste cigarettes, the high taste demand falls by more than the low taste demand ($M_H > M_L$). In the case illustrated in figure 1, the individual now finds it optimal to switch to low taste cigarettes.

If either the two high taste or the two low taste demand curves could be observed, the value of life could be measured directly from the observed shift. If the reduced life expectancy per cigarette is b_L and b_H for low and high taste cigarettes, the value of life is M_L/b_L or equivalently M_H/b_H. If, however, the individual reacts to the health risk by reducing the quality of cigarette smoked, it is possible only to observe the no-information demand for high taste cigarettes (HH' in figure 1) and the post-information demand for low taste cigarettes (L*L'* in figure 1.)

The observed shift in demand M in this case is comprised of two parts. M_L reflects the health cost of smoking the low taste cigarettes. M_{HL} reflects the utility cost to the individual of switching to low taste (low risk) cigarettes. While the latter shift component reflects a safety decision, it does not readily yield value of life information.[2/] The value of life can be calculated only by disen- tangling the product quality effect M_{HL} from the direct risk effect M_L; so that the value of life can be computed as M_L/b_L. The difficulty of disentangling these effects frustrates attempts to generate unbiased estimates of the value of life when the reaction to safety risks includes product quality changes.

Even if aggregate demand shifts could be decomposed to account for the quality component of the reaction, the classic selectivity problem in value of life studies remains--though in a somewhat different form. For some smokers, the information causes their demand curve to fall so much that no cigarette is worth smoking. In figure 1, the post-information demand curves for these individuals would fall completely below the price line P_c. In these cases, the observed demand curve shift M is truncated at the price P_c, and therefore these individuals' valuations of risk are not fully reflected in shifts in aggregate demand. Since individuals who value life highly are more likely to quit smoking when health costs become known, shifts in aggregate demand data generate biased estimates of the value of life.

Since the best data available on cigarette consumption over time is aggregate data, a methodology is needed which can use this aggregate information but in a way that accounts for the biases discussed. To do this, a model of individual choice is developed reflecting the analysis of figure 1. Individuals in the model are allowed to have different tastes for smoking, different values of life and, in some parts of the analysis, different beliefs about the life costs of smoking. The aggregate behavior predicted by the summation of individuals' choices can be compared to actual market data. The value of life distribution fitted to this data reflects the values of life held by different segments of the population including those who quit smoking and those who substantially changed their type of cigarette.

III. FORMAL MODEL OF OPTIMAL SMOKING BEHAVIOR

a. The Basic Model

Consider an individual who is an expected utility maximizer. Suppose that without health disclosures, the individual's decision to smoke is dependent upon price and a "taste" parameter. This "taste" parameter is fixed, and therefore the individual's optimal consumption of cigarettes does not change systematically with age; changes in the quantity of cigarettes consumed each period depend only on price. When new health information on smoking is released, the individual is assumed to adjust his belief (possibly, inperfectly) about the hazards of smoking and to reassess his rate of cigarette consumption. But once the information is incorporated, this rate will again depend only on price for the remainder of life.3/

The health cost of smoking is modeled as an increase in the likelihood of early death.[4] The individual has some perception of the increased risk of dying at each age in the future.[5] In particular, let q(i,Q,n) be the consumer's estimate of the probability of not having died from smoking at age i given that he smokes Q cigarettes per period with nicotine content n per cigarette. The risk of smoking is assumed to increase with the total consumption of nicotine;[6] that is, $q'(Q) < 0$ and $q'(n) < 0$.

If each period's utility is additive and independent of age, the individual's expected lifetime utility is

$$E(U) = \sum_{i=0}^{N} a^i p(i)q(i,Q,n)U(x,Q,n)$$

where i is age,[7] a is a time preference factor $(0 < a < 1)$, p(i) is the probability of being alive at age i if the individual does not smoke, and x represents the quantity of other goods consumed. It is also assumed that U is a well defined utility function; in particular

$$U_x > 0,\ U_{xx} < 0; U_Q > 0, U_{QQ} < 0; \text{ and}$$
$$U_n > 0 \text{ for } n < n^*,\ U_n = 0 \text{ for } n = n^* \text{ and } U_{nn} \leq 0$$

where U_j denotes the first derivative of U with respect to j; that is, all goods are positive arguments to consumption but nicotine content is valued positively only below a certain intensity level n*; beyond n* the cigarette becomes so "harsh" that further increments to n are valued negatively. Note that the model is not based on the simpler approach of describing utility as a function of total nicotine consumption. Empirical evidence clearly shows that consumers are not indifferent to the number of cigarettes they smoke.[8]

Normalizing so that the price of the representative good is unity, the per period budget constraint is

(1) $x + PQ = I$

where P is the price of the cigarettes and I is income per period (both assumed constant over life).[9] It is apparent from (1) that the money cost of smoking is assumed to depend only on the quantity and not the type of cigarette consumed.[10]

b. First Order Conditions

Maximizing expected utility E(U) subject to the budget constraint in (1) yields the first order conditions of interest to us:

(2) $$\sum_{i=0}^{N} a^i p(i)[q(i,Q,n)U_Q(x,Q,n) + q_Q(i,Q,n)U(x,Q,n) - \lambda P] = 0; \quad \text{and}$$

(3) $$\sum_{i=0}^{N} a^i p(i)[q(i,Q,n)U_n(x,Q,n) + q_n(i,Q,n)U(x,Q,n)] = 0$$

where λ is the marginal utility of income.

Condition (2) balances the expected marginal utility of consuming a greater number of cigarettes (first term) against the money costs of smoking plus the costs of reduced life expectancy from smoking at a higher rate of consumption. Condition (3) equates the marginal utility of smoking a better tasting (higher nicotine) cigarette (first term) to the value of expected reductions in lifespan from smoking stronger cigarettes.

Without health disclosures, the individual is assumed to consider the health cost of smoking to be zero; hence, q=1. The first order conditions in (2) and (3) therefore simplify to:

(4) $U_Q(x,Q,n) - \lambda P = 0$ and

(5) $U_n(x,Q,n) = 0.$

Condition (4) requires the individual merely to set the marginal utility of smoking an additional cigarette equal to its price. Condition (5) indicates that since nicotine content does not affect price, the individual should choose a cigarette type of sufficiently high nicotine content that the marginal utility of smoking a stronger cigarette is zero.

The effects of health disclosures on the consumer's optimal quantity-quality choice can be viewed in two steps. First, the consumer now realizes that nicotine is not a free good. While higher nicotine content does not involve additional money costs, it does reduce expected lifespan. Quality no longer comes as cheaply as originally thought. Thus, given any (money plus health) expenditure on cigarettes, the individual will substitute quantity for quality in his smoking habit. Second, with information, the consumer realizes that his actual expenditure of money plus health on cigarettes exceeds his perceived level of expenditures. As such, it is now optimal for him to reduce his total consumption of nicotine in terms of quantity of cigarettes and nicotine content per cigarette.

Let Q^* and n^* denote the no-information solution to (4) and (5). Let Q and n denote the post-information solutions to (2) and (3). Inspection of these conditions confirms the intuitive notion that health information causes the individual to reduce the number and the nicotine content of his consumption; thus, $n^* > n$ and $Q^* > Q$.

c. Optimal Choice Under Simplified Conditions

For purposes of estimation, the model is simplified in the following ways. First, for the no discount case, it is assumed that the individual approximates information on the health effects of smoking as a linear relationship between expected lifespan and the rate of nicotine consumed.[11/] Second, the individual assumes that if he quits at age j, his life expectancy will increase in proportion to the remaining portion of his life; thus, a person who quits half way through his adult life expects to gain half the increased lifespan as a young adult who quits as soon as he starts. These assumptions are stated succinctly as follows:

$$(6) \qquad E(T_j(Q,n)) = E(T_j(0,0)) - bnE(T_j(0,0))Q/n^*E(T),$$

where j is the age at which the information is received, $E(T_j(Q,n))$ is the expected lifespan at age j given a future consumption rate of Q cigarettes of type n and a past consumption rate of Q^* cigarettes of type n^*, and $E(T)$ is the expected lifespan of a non-smoker at age 0.

Third, and finally, utility is assumed to be a power function of nicotine. Since the no-information nicotine content is assumed to be n*, this relation is specified as

$$(7) \qquad U(x,Q,n) = U(x,Q,n^*) - k(n^*-n)^e Q,$$

where k and e are positive constants.

To derive preliminary results, the additional assumption is made that the rate of time preference is zero (a=1). The solutions reported below will be subsequently recomputed for the case where time preference is positive. Under these conditions, and ignoring second order terms,[12] post-informaton first-order conditions (described in (2) and (3)) simplify to:

$$(8) \quad -bnU(x,0,0)/\lambda n^*E(T) - k(n^*-n)^e/\lambda + U_Q(x,Q,n^*)/\lambda = P \quad \text{or}$$

$$-M_L - M_{HL} + U_Q(x,Q,n^*)/\lambda = P; \text{ and}$$

$$(9) \qquad -bU(x,0,0)/n^*E(T) + ek(n^*-n)^{e-1} = 0.$$

In particular, notice that our simple linear specification allows us to abstract from the age at which the individual receives the information.

The last term on the left side of (8) is the same as in the no-information demand curve (4), but two additional shift terms appear. The first, M_L, is the per-cigarette health cost of smoking a lower nicotine/lower taste cigarette. The second term M_{HL} reflects the per-cigarette cost of switching to an inferior tasting cigarette. These shifts correspond to those illustrated in figure 1.

The measure of the value of life in the model is apparent from these relationships. For an individual, the value of life is defined by the direct risk component of the shift M_L which reflects the perceived health cost of smoking n-type cigarettes. If n-type cigarettes are believed to cost bn/n*E(T) years of life per cigarette (as in (6)), the value of one year of life v is defined by

$$(10) \qquad v = n^*E(T)M_L/bn = U(x,0,0)/\lambda \,.$$

Since (10) relates the value of life to the unobserved demand shift M_L, it is also necessary to relate the value of life to the individual's observed demand shift M. To do this, the individual's nicotine choice is rewritten from (9) and (10) as:

$$(11) \qquad n = n^* - [bv\lambda/ekn^*E(T)]^{1/(e-1)}.$$

The total demand shift M can therefore be related to the value of life by rewriting (8) as:

$$(12) \qquad M = M_L + M_{HL}$$
$$= bv[n^* - ((e-1)/e)(bv/n^*E(T)ek')^{1/(e-1)}]/n^*E(T).$$

where $k' = k/\lambda$.

d. Aggregate Behavior

Most of the usable information describing smoking behavior is aggregate level data. The individual model must therefore be aggregated across the population to establish a connection to available statistics.

Let each individual have a different taste for smoking. In particular, the individual's marginal utility for smoking is parameterized by a taste scalar r whose distribution over the population is unknown. If individual taste differences are assumed to be constant across types of cigarettes, equation (7) can be rewritten to reflect individual tastes as

(7a) $U(x,Q,n,r) = U(x,Q,n^*,r) - k(n^*-n)^e Q.$

where k and e are constant but r varies by individual. Thus, the taste for nicotine is assumed constant over the population but the taste for cigarettes is not. A direct implication of this assumption is that, absent information, all consumers would smoke cigarettes of nicotine content, n*. The model is therefore consistent with historical evidence (see Appendix).

Absent health information, at price P, there is a taste parameter threshold r'(P) that separates smokers from non-smokers; individuals with a larger taste parameter smoke, those with a smaller taste parameter do not. The aggregate demand for cigarettes when the health risk is unknown is then given by

$$(13) \qquad Q^*(P) = \int_{r'(P)}^{\infty} Q(P,r)f(r)dr$$

where Q(P,r) is the quantity demanded (from (4)) and f is the density of tastes over the population. The percentage of the population that smokes prior to health disclosures is given by

$$(14) \qquad S^*(P) = \int_{r'(P)}^{\infty} f(r)dr.$$

Once information on the hazard of smoking is received, the individual's demand for cigarettes falls in accordance with equation (8). For the first part of the analysis, all consumers are assumed to hold the same beliefs about the life cost of smoking (reflected by the parameter b). For convenience, the new quantity demanded is denoted by Q(P,r,M) where $M = M_{HL} + M_L$ is the shift term in equation (8). Finally, it is clear that the taste parameter threshold separating smokers from non-smokers after information will depend on the the sum P+M. Post-information aggregate demand is then given by

$$(15) \qquad Q(P) = \int_0^{\infty} \int_{r'(P+M)}^{\infty} Q(P,r,M)f(r)dr\ g(M)dM$$

where g(M) is the density function describing the distribution of individual reactions arising from differing values of life. The proportion of the population that smokes after health disclosures is given by

$$(16) \qquad S(P) = \int_0^{\infty} \int_{r'(P+M)}^{\infty} f(r)dr\ g(M)dM.$$

Finally, it is noted that, contrary to the no-information equilibrium, the optimal nicotine-type cigarette will differ across smokers. Since cigarette choice is now a function of the individual's value of life (see equation (11)), a distribution of types of cigarettes will now be observed in the market.

IV. ESTIMATION OF THE VALUE OF LIFE SAVING

a. Methodology

Equations (13) through (16) establish the relations between aggregate data and underlying individual distributions. The left hand sides of these equations are known data. Similarly, the distribution of nicotine choices implicit in equation (11) is known. Thus, our methodology uses these equations to infer the taste and shift distributions f(r) and g(M) and, in turn, to calculate the value of life distribution.

Cigarette smoking data is available that describes actual smoking behavior in 1980, including the total quantity of cigarettes consumed, the elasticity of demand for cigarettes, the percentage of the population smoking and the distribution of the types of cigarettes smoked. Abundant data is also available to estimate how these smoking patterns would have differed in 1980 had no information been provided on the health hazards of smoking. These data and estimates are summarized in table 1 and are presented in more detail in the Appendix.

Since there are no longitudinal micro data sets that track individual smoking patterns over time, traditional statistical techniques cannot be used to fit the underlying distributions in the model.13/ Instead, particular functional forms for individual demand curves and for the underlying distributions of taste and the value of life are assumed. By iterating on the unknown parameters of these functional and distributional forms, the model which best fits the known aggregate data is determined. The taste and demand shift distributions are fitted to aggregate data first; the value of life distributions are then calculated.

b. The Distribution of Tastes for Smoking

Consider cigarette consumption in a no-information world. Assume that individuals have demand curves of the form

(17) $$Q = r - cP/r$$

for n*-type cigarettes where the constant c is equal for all consumers, and where the taste parameter r varies across individuals.14/

The taste parameter is assumed to be positive and distributed across individuals in such a way that the corresponding quantities have a beta distribution of the form $h(Q) = B(a,b)(Q+L)^{a-1}(T-Q)^{b-1}$ where B is the beta function; the shape parameters a and b and the right endpoint T are positive.15/ The left endpoint -L of the distribution is allowed to be negative to reflect the possibility that some individuals would have to be paid to smoke. Finally from equation (17), it follows that individuals will not smoke at price P if their taste parameter r is less than the threshold $r'(P) = (cP)^{1/2}$.

Under these assumptions, for any choice of the parameter c and for any appropriately specified taste distribution on r, aggregate demand without health disclosures can be derived from equation (13). By iterating on the parameters c, a, b, L and T, the model can be solved to be consistent with the following facts (presented in table 1): Absent information, the per capita quantity smoked would have been 386 packs per year in 1980 at the (1980) price P_c=\$.656 per pack; the elasticity of aggregate demand would have been -.48; and 54.2 percent of the population would have smoked.

The solution is characterized by c*=505,000 and a quantity distribution denoted by h*(Q) with shape parameters a=9 and b=2.7 and endpoints -L=-6300 and T=1875.[16/] This solution of the no-information model gives us the baseline from which to measure the reaction to cigarette information.

c. The Distribution of Individual Demand Shifts M

Once the information on the hazard of smoking is available, the individual's demand curve (specified by (17), (12) and (8)) becomes

(18) $$Q = r - c(P+M)/r$$

where M is the individual's shift in demand attributable to the combined effect of the switch to an inferior tasting cigarette and the perceived health risks of smoking that cigarette. Those consumers whose taste parameter r is less than the new higher threshold $r'(P,M) = (c(P+M))^{1/2}$ will not smoke. All consumers are assumed to treat the hazards of smoking as a cost; that is, $M > 0$. Finally, the distribution of demand shifts is assumed to be a beta distribution with the density $g(M) = B(aa,bb)M^{aa-1}(TT-M)^{bb-1}$ where the shape parameters aa and bb and the endpoint TT are positive constants.

The demand shift distribution $g^*(M)$ which fits the observed aggregate data is found iteratively as follows: Using the no-information quantity distribution $h^*(Q)$ and the parameters s^* and c^* determined above, any specified distribution for the individual demand shifts M will generate a post-information demand curve as in equation (15). By iterating on the shift distribution parameters aa, bb and TT, the post-information model can be made to fit the following facts (summarized in table 1): In 1980, the per capita quantity smoked at the price P_c=\$.656 is 195 packs per year; the price elasticity of demand is -.48; and 32.5 percent of the population smokes. The shift distribution which fits this data has the shape parameters aa=1.00008, bb=5.957 and the endpoint TT=8.[17/]

The mean of the estimated shift distribution is \$1.15; the standard deviation of the distribution is \$.99. The estimates suggest that, in 1980, if cigarettes could have been purged of risks, consumers (including smokers and non-smokers) would have been willing to pay an additional \$1.15 on average beyond the out-of-pocket costs (\$.656) for a pack of their favorite cigarette. Using the standard errors that underlie the aggregate estimates, a confidence range between \$.91 and \$1.28 was established for this estimate.[18/]

It is interesting to compare the \$1.15 mean demand shift estimate to the observed shift in per capita demand that can be attributed to cigarette-health disclosures. This per capita shift which is easily derived from table 6 in the Appendix is \$.935. The discrepancy between these two measures occurs because the reactions of those who quit smoking are not fully reflected in the aggregate data. Thus, our estimate suggests that use of the observed per capita shift would underestimate the actual reaction to cigarette information by approximately 20 percent.

It is also worth noting that the fitted individual demand shift distribution is not tight; almost 20 percent of the population had demand shifts exceeding $2 while 54 percent had shifts of less than $.50. In short, in order to explain the facts in the aggregate data, it must be true that individuals reacted in very different ways to the same announced health-disclosures. The shift distribution is also sharply humped near zero, suggesting that many individuals reacted weakly to cigarette-health disclosures.

d. Calculating the Value of Life

The distribution of individual demand shifts is not sufficient to determine the value of life saving, because the shift also incorporates the reduced value of smoking the inferior tasting cigarettes. To estimate the value attached to the life saving alone, the quality effect must be disentangled from the direct risk effect.

To address the disentanglement issue, additional information available on cigarette smoking patterns is exploited. In particular, data describing the distribution of cigarette choices (in terms of nicotine content) in 1980 is available; data is also available which permits an estimate of what this distribution of choices would have been in 1980 without information (see Appendix). These facts about cigarette choices make it possible under different assumptions about consumer beliefs to solve the model for the value of life distribution which is most consistent with the estimated shift distribution and with the observed nicotine choices (recall equations

11 and 12). The algorithm also generates separate distributions for M_L and M_{HL}.

The solution to the model is found iteratively. Assume that consumers hold a particular belief, reflected in the parameter b, about the life cost of smoking. It is apparent from equation (12) that, for any assumed nicotine preference parameters e and k', a value of life distribution can be computed directly from the shift distribution g*(M) determined above.[19] By iterating on the preference parameters e and k', the corresponding nicotine distribution which minimizes the sum of squares distance from the known nicotine distribution can be determined. That is, the nicotine density generated by the model, denoted by $J_{k',e}(n)$ can be compared with the known nicotine density j(n) given in the Appendix;[20] the best fit solution is determined by the criterion

$$\min_{k',e} \int_0^{n^*} [J_{k',e}(n)-j(n)]^2 dn.$$

The corresponding value of life distribution is taken as the solution to the model.

Our primary estimate of the value of life distribution is based on the assumption that consumers believe the expected life loss from smoking a pack a day to be 3.5 years -- an assumption that is consistent with the best medical evidence available on life expectancy effects.[21] Using the best demand estimates above (characterized by the $1.15 mean demand shift), the model solution is found to have values of e = 3.0 and k' = 1.2, with the sum of squared differences for the nicotine distributions equal to .029.

The first result worth noting is that the means of the direct risk and the switching components of the shifts are M_L = \$.86, and M_{HL} = \$.29. Thus, approximately 75 percent of the individuals' mean demand shift of \$1.15 is attributable to the life cost of smoking the relatively safe (low taste) cigarettes that were consumed in 1980. The remaining 25 percent of the reduction is attributable to the smokers' switching from higher to lower quality cigarettes.

These estimates provide a basis for determining the degree of bias inherent in methodologies that ignore quality reactions to the announcement of risk. If the position were adopted in this study that "a cigarette is a cigarette," the value of life would be estimated as M/b_H where b_H is the life loss per pack of high taste cigarettes. This apprcach would underestimate the mean value of life by approximately 10 percent.[22] Alternatively, one could argue that the reduction in demand would more appropriately be matched to the risk b_L remaining in the low tar cigarettes, that is, that the mean value of life is computed as the mean of M/b_L. In this case, the measure would be approximately 50 percent higher than it should be.

These simple computations demonstrate the potential importance of explicitly treating the quality reaction to risk. It should be noted, however, that these results do not imply that the first method (M/b_H) should be preferred, since the relative magnitudes of the errors would have been reversed if the value attached to the quality switch had been higher than the direct risk effect. There is no theoretical reason to preclude this.

The estimated value of life distribution is shown by the downward sloping density function in figure 2. The mean value of the distribution is $8,622 (1980 dollars); the standard deviation is $9,170. We will discuss the characteristics and shape of the distribution first, then address the significance of the mean value itself.

The significant spread of the estimated distribution is an important feature of the results and one which survived various sensitivity analyses. The variation across the population suggests that the value of life is substantially different for different segments of the population. As such, concern about selectivity problems that color estimates of the value of life could be significant depending on the sample basis for the estimate. For example, if comparably risky jobs attract individuals from the lower 25 percent of the population in figure 2, the estimated value of life determined from wage premiums attached to those risky jobs should yield a value of life of less than $3,200 per year. In contrast, if certain types of safety items are purchased by those in the upper 25 percent of the distribution, the value of life reflected by the market would be approximately $12,000 per year.

This point is also forcefully made by a comparison of smokers with non-smokers. If, in the estimate described here, the average value of life is computed for smokers alone, the value of a year of life is $5,700; the corresponding value for non-smokers alone is $10,500 per year. These estimates clearly illustrate the potential bias inherent in methodologies that estimate values of life based on observed risk premiums received by the risk-takers alone.

The estimated value of life distribution is not only dispersed but it also exhibits its highest density near zero, falling monotonically over higher values of life. While this result may violate prior expectations about nicely humped distributions, it is in some sense inevitable in light of the empirical finding that a substantial portion of the population exhibited a small reaction to the cigarette-health information. Under an assumption that all consumers hold the same belief about the health cost of smoking, the empirical finding of a relatively high frequency of weak reactions to health warnings translates directly to the inference that many individuals have relatively low values of life.

The shape of the value of life distribution raises the issue of consumer beliefs in a striking way. If consumers do not share the same belief about the life cost of smoking, the unexpectedly high density of small values of life might be simply a symptom of the misspecified belief assumption. This issue is explored more fully below. Allowing for differing consumer beliefs can be shown to change the results in expected ways, but does not fundamentally alter the qualitative nature of the results described here.

Before accommodating this complication, however, it is worth considering the magnitude of the mean value of life in more detail. First, the results were tested for sensitivity to various critical inputs. In particular, using the range of estimated shift distributions developed above (recall that the statistically acceptable range of distributions had means varying from $.91 to $1.28), and also allowing the beliefs about the life lost from smoking to range between two to five years (but fixed across individuals), the mean value of a year of life is estimated to be between $4,186 and $16,008 (see table 2).

These estimates are not directly comparable to other estimates of the value of life in the literature, because this measure is for a year of life while previous measures have been for a population facing a risk of immediate death. Recalling the initial assumption, however, that the time preference rate is zero, the annual value can be converted to the usual measure by taking the expected present value of the annual measure at the average age of the population used in other studies.[23/] Performing this exercise, the comparable value of life is estimated to be between $146,510 and $560,280. These estimates are presented in the first row of table 3.

V. VALUE OF LIFE ESTIMATES WITH SUBJECTIVE DISCOUNTING

The value of life estimates to this point have been based on an assumption that consumers do not exhibit time preference (beyond that induced by the uncertainty of survival). However, assumptions about consumer time preference play a potentially important role in the methodology for estimating the value of life.

A hazard like smoking is characterized by significant lags between consumption and its ultimate health effects. When new information about the hazard is released, the individual considering a reduction in consumption incurs a utility cost throughout his life for the sake of benefits that are concentrated later in life. If the individual is discounting these future benefits, a methodology that matches his observed reduction in demand to undiscounted life saving benefits will lead to underestimates of the value of life.[24/]

Mortality data is available to estimate the timing of deaths for smokers relative to non-smokers. In particular, a function of the form $P_e = A\exp(K/Age^2)$ where P_e is the difference in the probability of death for smokers relative to non-smokers was fit to data available from a study of mortality patterns of smoking and non-smoking U.S. Veterans (HEW

1979); the coefficients A = -.59 and K = -6316 provided the best fit (R^2 = .98). For purposes of estimation, individuals are assumed to know the basic shape of this excess death function. A multiplicative scaling factor is used to generate different beliefs about the number of years of expected life lost through smoking.[25/] As in the case of no discounting, the scaling parameter was set to reflect a range of assumptions about life expectancy beliefs (see table 2).

Arguably, the appropriate time preference rate for this context is bounded by the real interest rate.[26/]. Fisher and Lorie (1977) have put this rate at no more than 2.5 percent over the last 50 years. To allow for the possibility that imperfections in the capital market inhibit time preference from being fully reflected in the observed interest rate, time preference rates up to 5 percent were also considered.

By incorporating these discount rates and the associated excess death function P_e into the algorithms discussed above, revised value of life distributions were fitted. The results are presented in rows 2-4 in table 3.

When the time preference rate is set equal to the interest rate .025, the best no-discount estimate of $301,770 increases to $368,495. Doubling the time preferences rate to .05 increases the estimate to $503,132. The lower and higher bound estimates under the no-discount assumption increase by similar amounts. In short, while the introduction of discounting does increase the measured values of life, these increases are not large enough to change the order of magnitude of the results.

The results in table 3 are relatively low when compared to previous estimates of the value of life. Blomquist (1979) and Thaler and Rosen (1975) generate results that are in the $450,000 - $500,000 range (1980 dollars). Our best estimates are approximately two-thirds as large as these estimates without discounting, and just as large with discounting at a rate of 5 percent. Similarly, the estimates are considerably below other estimates in the literature that range from $1 million (1980 dollars) to almost $3 million per life saved (Brown (1980); Smith (1976); Viscusi (1978)). Thus, when compared to previous studies, our results to this point support the use of generally lower values of life.

VI. VALUE OF LIFE ESTIMATES WHEN CONSUMER BELIEFS ARE NOT IDENTICAL

The estimates presented above are based on the assumption that all consumers have the same assessment of the life loss due to smoking. While this assumption has been widely used in the literature, it is troublesome on theoretical and empirical grounds. If some individuals accept relatively high risks, it can be inferred that either they have relatively low values of life or they have relatively low estimates of the risks. For example, in terms of figure 2, the high frequency of low values of life could suggest that a substantial portion of the population simply underestimates the life cost of smoking.

To the extent that individuals with weak responses believe the life costs are relatively low, their computed values of life should be higher than the level reflected in figure 2. Similarly, consumers who reacted strongly to the hazard information but who hold higher estimates of the life cost should be computed to have lower values of life. The net effect of these competing adjustments on the mean value of life depends on the particular belief distribution held by the population. However, the variance around the mean is expected to fall because part of the previously observed variance is now attributable to differences in beliefs.

While reliable belief information is not typically available, a nationally projectable survey was conducted by the Roper Organization for the Federal Trade Commission in November 1980. Individuals were asked to judge the truthfulness of an assertion that a 30 year old pack-a-day smoker had a lower life expectancy than a comparable non-smoker.27/ Those who answered in the affirmative were then asked how many years of life were lost on average. The survey results are shown in table 4.

While these results are suggestive of consumer knowledge of smoking risks, some problems are evident. For instance, 30 percent of the population (and 40 percent of smokers) deny that smoking affects life expectancy. Yet, these responses are directly contradicted by the individuals themselves in other parts of the survey, and by overall market response behavior.28/ Notwithstanding these shortcomings, the survey results suggest several qualitative features of current consumer knowledge of smoking.

First, on average, individuals do not appear to underestimate the risk of smoking. Taking the survey results at face value, and ignoring the non-responses, the mean life loss is approximately 3.5 years, which closely corresponds to epidemiological results (see note 21/).

Second, the belief distribution is not symmetric; even if zero-cost responses are eliminated, the distribution is skewed to the left. While a greater number of consumers apparently underestimate the life loss of smoking, those who do overestimate do so by a greater margin on average.

Third, and finally, the distribution exhibits a high variance. For instance, including the zero-cost respondents in the lowest cost group, the standard deviation of the Roper distribution is 4.3 years, thereby suggesting that the dispersion of beliefs about the mean life loss could be quite high.

The deviations in reported beliefs are large enough to introduce the possibility that the estimated values of life reflected in table 4 and the corresponding distributions are largely an artifact of the uniform belief assumption. To investigate this issue, the value of life distribution was reestimated incorporating the Roper survey data. For this purpose, consumers who responded that smoking had no life expectancy effects were placed in the lowest Roper category of 0-2 years lost per pack;29/ consumers in each category are assumed to be uniformly distributed across the category. This belief distribution has a mean of 4.3 years. It is also assumed that an individual's reported belief about the life cost of smoking is independent of his underlying taste for cigarettes r and his value of life v.

With appropriate adjustments to the solution algorithm, the model can be solved under the Roper belief assumption.30/ The solution is characterized by parameters e = 3 and k' = 1.2 and a value of life distribution with a mean of $8,500 per year of life and a standard deviation equal to 70 percent of the mean (roughly, $6,000). In contrast, when the value of life distribution is computed for a uniform belief of 4.3 years, the mean value of life is found to be $6,950 with a standard deviation equal to 106 percent of the mean (roughly $7,415).

The value of life distribution for the Roper belief distribution is shown by the humped density function in figure 2. The corresponding uniform belief case (4.3 years) is very similar to the uniform belief case of 3.5 years also shown in figure 2. As expected, the introduction of differing consumer beliefs acts to reduce the variance of the value of life distribution; the mass of the distribution is also decidely pushed away from zero. More importantly perhaps, the Roper belief assumption increases the mean value of life by approximately 20 percent, from $6,950 to $8,500 per year. This increase is primarily attributable to the net reduction in the density of individuals near zero. It is interesting to note, however, that despite the decidely skewed nature of the Roper survey responses, the fitted value of life distribution continues to have a clear non-symmetric character with a concentration of density at lower values. Moreover, while somewhat diminished in strength, our previous findings of a substantial variation in individual values of life remains.

VI. CONCLUSION

Using a time series approach, this study found that cigarette-health disclosures led to a reduction in the demand for cigarettes of $1.15 on average. The shift can be compared to the 1980 price per pack of cigarettes of $.656. From these reactions, the best estimates of the average value of life held by the population were put in the range of $300,000 to $500,000. Various sensitivity tests confirmed that the results were robust.

The paper also identified and quantified several biases that plague value of life studies. For example, had observed aggregate cigarette demand been used to estimate the per capita shift due to cigarette-health disclosures, the average value of life would have been understated by about 20 percent. The error occurs because the reactions of consumers who left the cigarette market are not fully measured. It is also shown that individuals' demand reactions are comprised of two parts, one that reflects a direct value of life discount and one that reflects the reduction in the quality of cigarette smoked. The latter effect accounted for approximately 25 percent of the total observed reduction in cigarette demand. Ignoring the quality reaction to health disclosures would have led to errors in calculating the value of life that ranged from 10 to 50 percent in this study.

The time series approach, together with efficient use of available data, permits an estimation of the distribution of values of life held by the population, not just the mean values. Persistent smokers in 1980 exhibited values of life that were generally less than two-thirds the average for the population and less than one-half the value for non-smokers. The large dispersion in values of life across the population confirms suspicions that the appropriate value of life for policy or other purposes can differ substantially depending upon the segment of the population affected.

The model was modified to accommodate varied consumer beliefs about the life cost of smoking. Replacing a uniform belief assumption with survey data that showed a wide variation in beliefs around the same mean changed the results significantly. The estimated mean value of life increased by 20 percent and the standard deviation fell from over 100 percent to within 70 percent of the mean. Still, while the potential for varied beliefs to substantially alter the results was demonstrated, the order of magnitude of the primary quantitative results did not change.

A clear lesson of this study is that reliance on self selected risk takers in cross section studies can lead to seriously biased results. If time series studies are performed to accommodate these biases, it is inevitable that the emphasis of value of life studies must move towards health hazards and away from accidental risks. In the case of accidents, risks are more apparent and therefore offer little chance to observe observe market reactions to new information about risks. The study of health hazards, however, inevitably requires an explicit treatment of time preference rates as well as estimates of the time profile of the mortality effects over individual lifetimes. They also require more attention towards the question of consumer beliefs. Routinely assuming that consumers hold correct expectations about health hazards is a problem that plagues all value of life studies. But it may be more troublesome for newly announced health risks. First, in the case of health hazards, there is an indirect connection between consumption and its ultimate consequences, and second, it may take considerable time for the population to assimilate the full implications of newly announced hazards.

Future studies could significantly benefit from access to longitudinal micro data sets which include behavioral and belief information. In this paper, various distributions were inferred from available pieces of information describing aggregate behavior. More reliable results and better concepts of standard errors around these results could be found by studying many individuals' reactions over a similarly critical time period. While such data bases are rare, they could significantly improve our knowledge of the way individuals react to risk and the role consumers' own estimates of health cost play in determining their behavior.

Finally, it is worth highlighting a few features of the results that are useful for policy application. Policymakers sometimes have difficulty dealing with value of life estimates that are generated by the compensation principle. Their criticisms are based on arguments that individuals do not know the health costs of risks; that workers cannot move from dangerous jobs because they are either heavily invested in particular firms or are otherwise immobile; that different individuals have different values of life, and finally, that some individuals cannot "afford" to avoid risks.

The case of cigarettes may provide a particularly useful example to deal with these problems. Available evidence does not support either the notion that individuals, on average, are unaware of the life cost from smoking, or that addiction (the counterpart to job immobility) is a significant problem in the case of cigarettes.[31/] The estimates also permit quantification of the extent to which values of life actually differ across the population. Finally, rather than dealing with the difficult question relating to the "affordability" of risk avoidance, the case of cigarettes permits us to use an example where individuals actually must pay an out-of-pocket cost for opportunity to expose themselves to risks. The popular retort that low income individuals (who incidentally smoke more than high income individuals--see Ippolito et al. 1979) cannot "afford" to purchase a safety device is thwarted without resorting to awkward arguments about marginal vs average utilities of consumption.

APPENDIX

Effects of Disclosure on Per Capita Cigarette Consumption, Nicotine Content and the Smoking Participation Rate

The history of cigarette health disclosures has been given elsewhere, and therefore is not repeated here (see, e.g., Ippolito et. al. 1979 or Klein et. al. 1981). In essence, the health hazards of smoking were widely publicized starting around 1952, culminating in the now-famous Surgeon General's Report in 1964. Numerous additional Reports and much additional publicity have ensued. In this Appendix, estimates are made of what per capita cigarette consumption, nicotine content per cigarette smoked and the overall smoking participation rate would have been in 1980 if no health disclosures had ever appeared. These estimates are compared to actual behavior that characterized the cigarette smoking market in 1980.

Per Capita Cigarette Consumption

In 1980, per capita cigarette consumption was 195 packs per year (U.S. Department of Agriculture, 1981). The per capita consumption that would have occurred without disclosures is estimated by analyzing aggregate cigarette consumption in the U.S. over time.

Several studies have used somewhat different methodologies to measure the effects of cigarette-health publicity on per capita cigarette consumption. The results have all been similar.[32/] In this appendix, the results presented in Ippolito et. al. (1979) which included data up to 1975 are updated through 1980. Following the same methodology, the following specification of cigarette consumption from 1934-1980 was estimated:

$$c = b_0 + b_1 t + b_2 D53/(1-e^{dT53}) + b_3 D64\ T64 + b_4 P + b_5 y + \text{error}$$

The variable c is the log of the number of cigarettes consumed per adult (age 18 and over) in the U.S., P is a BLS real retail price index, y is the log of deflated per capita income and t is the log of a trend term. The term D53 denotes the appearance of initial health disclosures and subsequent publicity and equals one during the period 1953-1980 and zero otherwise; D64 denotes the appearance of the Surgeon General's Report and subsequent publicity and equals one during the period 1964-1980 and zero otherwise. T53 is a time counter beginning at one in 1953 and T64 is a counter beginning at one in 1964. Iteration on d in increments of .25 resulted in the best fit of the equation when d equaled -4.0; b_2 is the long term percentage reduction in consumption owing to the 1953 disclosures and subsequent publicity, assuming that the Surgeon General's Report had never appeared.

The estimates using ordinary least squares are presented in equation 1 in table 6.[33/] The estimates on the health dummy variables suggest that the 1953 health disclosures and subsequent publicity led to a long term decrease in per capita consumption in the vicinity of 17 percent, and that the Surgeon General's Report and subsequent publicity led to an additional gradual reduction in per capita consumption on the order of 3.17 percent per year through 1980.

Together, these measures suggest that per capita cigarette consumption in 1980 was 50.4 percent of what it would have been absent the appearance of smoking-health publicity. Thus, without the appearance of disclosures, per capita consumption would have been 386 packs per year in 1980 compared to actual consumption of 195 packs per year.

Nicotine Content

The relative harm associated with smoking a particular type of cigarette can be indexed by its nicotine content.[34/] Nicotine content by brand and variety is available from the Federal Trade Commission. Corresponding market share data is available from J. P. Maxwell (see references). While the value of life calculations in the text require the distribution of smokers across nicotine types, it is well documented that smoking intensity is invariant to cigarette-type (see Ippolito, et. al. 1979; Health Consequences of Smoking 1981); hence, the distribution of market shares across nicotine-type cigarettes is equivalent to the distribution of smokers across nicotine-type cigarettes.

a. Smoker Distribution Across Cigarette Types With Disclosures

The actual distribution of nicotine cigarette types in 1980 is calculated directly from the FTC and Maxwell data. The nicotine brand data was used to aggregate market shares across similar brands of cigarettes. The resulting nicotine market share distribution was fit with the following logistics equation:

$$(21) \qquad \log(Z/(1-Z)) = \underset{(49.09)}{-5.11} + \underset{(50.47)}{5.66\, n}, \qquad R^2 = .99,$$

where n is nicotine content, Z is the proportion of cigarettes sold whose nicotine content is less than or equal to n and the numbers in parentheses are t-statistics. This distribution is characterized by a mean nicotine content of approximately one milligram per cigarette.

b. Smoker Distribution Across Cigarette Types Without Disclosures

What types of cigarettes would individuals have smoked in 1980 if disclosures had not appeared? A clue to the answer is provided by historical evidence. Prior to 1952, a few non-filter cigarettes with very similar nicotine contents dominated sales for over twenty-five years (J. P. Maxwell). If nicotine content within brands is assumed to be constant prior to 1952, the weighted nicotine content per cigarette smoked was virtually stable from 1926 to 1952. Therefore, it is reasonable to assume that absent the intervening disclosures nicotine content would have remained constant and virtually all cigarettes would have had the same nicotine content. For estimation purposes, the limiting assumption is adopted that all cigarettes would have been identical.35/ Using the FTC and Maxwell data, the nicotine content of these no-information cigarettes is put at 1.49 milligrams.36/

Smoking Participation Rate

The actual participation rate in 1979 is used as our best guess of the smoking participation rate in 1980. As of 1979, 32.5 percent of the adult population smoked cigarettes (Health Consequences of Smoking, 1981). To determine the proportion of adults that would have smoked but for the health disclosures, smoking participation rates over time were examined.

Participation rates for the age group 21-47 years old were available annually from 1947-1975 (H.E.W., Adult Use of Tobacco, 1975);37/ these data were analyzed using numerous alternative dummy variables to fit consumer reactions to health disclosures. The following specifications provided the best fit to the data:

$$a = c_0 + c_1 t + c_2 D53 + c_3 D64\ (T64)^2 + c_4 P + c_5 y + \text{error}.$$

where a is the smoking participation rate (all other variables were described above). The equations were run with and without the price and income variables.[38/] The estimates are presented in equations 2 and 3 in table 6.

These results clearly reject the hypothesis that the 1953 disclosures and subsequent publicity had a lasting negative impact on consumers' collective probability of smoking. In contrast, the response to the 1964 Surgeon General's Report is negative and significant, suggesting a large long term impact of the post 1964 health disclosures on smoking participation rates. It can be inferred from these estimates that absent health disclosures, the participation rate would have been 54.2 percent in 1980.

The data developed above is summarized in table 1 in the text.

FOOTNOTES

1/ For more complete reviews of the literature, see Bailey (1980), Blomquist (1980), Brown (1980) and Smith (1979).

2/ The shift M_{HL} reflects the savings in life generated by the switch to less harmful cigarettes, measured by $b_H - b_L$. However, $M_{HL}/(b_H - b_L)$ understates the true value of life. In an n-quality model, the individual can be thought of as making a series of switches to lower nicotine cigarettes. At first, the reductions in tastes are outweighed by increases in life expectancy; and so, the individual continues to switch to ever poorer tasting cigarettes until these factors exactly balance. Thus, the sum of life expectancy gains from the infra-marginal switches exceeds the sum of the utility costs of smoking lower taste cigarettes.

3/ We chose not to model smoking as an addiction in the sense that quitting imposes a physical withdrawal cost on the individual. If the addictive characteristics of smoking were important, it would follow that after 1964 (the date of the first Surgeon General's report), the reduction in start rates would have been proportionally larger than the corresponding reduction in overall participation rates; that adjusting for other factors, pre-1964 starters would smoke either more cigarettes or higher nicotine content cigarettes than post-1964 starters; and that post 1964 quit rates would be lower for older smokers than for younger smokers. Available empirical evidence rejects these hypotheses. See Ippolito et. al. (1979).

4/ The money cost and the disutility cost of a smoking-related fatal illness are not necessarily higher than those that would otherwise be incurred for an unrelated fatal illness. Lower health levels that may be caused by smoking during life (shortness of breath, coughing, etc.) were presumably more widely known, and therefore internalized, prior to disclosures. For these reasons, the primary health cost of smoking is taken to be a reduction in life expectancy.

5/ Replacing this assumption with a weaker one--that the individual has a perception of the effects of smoking on expected lifespan--does not affect the no-discount results generated below.

6/ Nicotine is highly correlated with other determinants of the smoking risk, e.g., tar and carbon monoxide.

7/ All ages are taken in reference to the age when the smoking decision is made, so that age $i = 0$ refers to the starting age.

8/ More particularly, in a world in which utility is a function of total nicotine intake, rather than quantity of cigarettes and nicotine content separately, all smokers would smoke one very strong cigarette per period. They would do so because cigarette prices are generally insensitive to nicotine content. The fact that smokers pay for the opportunity to spread their nicotine intake over many cigarettes daily rejects models that pose utility as a function only of nicotine intake.

9/ This simplifying assumption could be relaxed to include an overall wealth constraint with variable income over life and savings possibilities. However, these generalities are superfluous for the a consideration of smoking behavior.

10/ The price of same-sized cigarettes is generally insensitive to the tar and nicotine content per cigarette.

11/ In fact, the evidence suggests diminishing mortality effects from the higher rates of smoking and a lagged health response to reduced consumption (U.S. Department of Health, Education & Welfare 1979).

12/ In particular, it is assumed that the utility of smoking is small compared to the utility of living and consuming all other goods.

13/ Occasional snapshots of cross section behavior have been taken. However, these data sets are generally not comparable and do not cover pre-1965 behavior. In addition, it is widely known that the distribution of reported quantities of cigarettes smoked in these samples is inconsistent with verifiable aggregate data (see Warner, 1979). Thus, available cross section quantity data is less abundant and less reliable than aggregate quantity data.

14/ Other simple specifications where the slope of demand was not allowed to vary by individual were decidedly inferior in fitting available data. In addition, a more general form of the demand curve was investigated where price P was raised to a power, but values of the power different from unity did not generated better fits to the data.

15/ A beta distribution was chosen here because the available (though suspect) cross-section information on individual smoking quantities shows a definite left skew across individuals.

16/ There are multiple solutions for this portion of the model. These solutions are characterized by small changes in the tails of the distribution which do not significantly change the mean and standard deviation of the fitted distributions. The results reported below are not changed if these alternative solutions are used. In addition to satisfying the aggregate empirical criteria set-out above, the solution was checked against two additional criteria. First, the aggregate demand curve implicit in the model was shown to be essentially identical to the estimated per capita demand presented in table 6 in the Appendix. As a further check, the implied quantity distribution for smokers was compared to actual smoking intensities prior to health information (HEW 1979); adjusting for the usual underreporting bias in these surveys (Warner 1979), the results were consistent.

17/ Small changes in the right tail of the distribution did not significantly change the results.

18/ The estimates of smoking behavior in 1980, absent information, are subject to statistical error (see table 6). Using the 95 percent bounds for the estimates, the model was again solved for the corresponding demand shift distribution. The fitted shift distributions for this range of criteria were characterized by means ranging from \$.91 to \$1.28.

19/ In particular, the density for the values of life is $h(v) = g(M(v))[b(n^*-(bv/n^*E(T)ek'))/n^*E(T)]^{-1}$ where $g(M)$ is the density function for M determined above and $M(v)$ is the demand shift corresponding to the value of life v (from (12)).

20/ The density for the nicotine choices generated by the model is $J_{k',e}(n) = h(v(n))n^*E(T)k'e(e-1)(n^*-n)^{e-2}/b$ where h is defined in Footnote (17) and $v(n)$ is the value of life corresponding to a particular nicotine choice (from (11)).

21/ Based on smoking surveys and subsequent follow-ups upon the death of respondents, several studies have estimated the effects of smoking on life expectancy. The estimates are generally based on the consumption of pre-information nicotine content cigarettes. Standardizing to the same intensity levels, the results range from 2.3 to 4.8 years of expected life lost for lifetime pack-a-day smokers (see Ippolito, et. al. 1979; Hammond 1967; U.S. Department of Health, Education & Welfare 1979). Consumers' perception of mortality warnings appear to be consistent with these estimates. Hamermesh (1981) conducted a survey of 26-39 year old academics. Other things constant, smokers in his sample estimated their life expectancies to be 3.5 years shorter than non-smokers. In a Roper survey conducted for the Federal Trade Commission in 1980, respondents estimated that a lifetime pack-a-day habit would result in a reduction in life expectancy of about 4 years.

22/ That is, since tar is assumed to be linearly related to life expectancy and since average nicotine per cigarette fell from 1.49 mg to .97 mg, the life loss for the low tar cigarette b_L is about two thirds that of the high tar cigarette b_H. Thus, the average value of life M_L/b_L is $\$.86/b_L$ and the alternative measure is $M/b_H = \$1.15/(3/2 \times b_L) = \$.77/b_L$.

23/ In most wage studies, for instance, the value of life calculation refers to the average male worker who is approximately 37 years old. Expected lifespan at this point is approximately 35 years. Therefore, without time preference, our best estimate of the comparable average value of life derived from our measure is equal to the annual measures times a factor of 35.

24/ Previous studies estimate the expected present value of future losses in utility if the individual does not die from an instantaneous risk (long term health hazards have not been considered). These estimates reflect consumer discounting, if it exists. The same approach could be used for the cigarette measure, but the resulting "value of life" would be applicable only to other hazards with the same pattern of risk over life, that is, with the same lagged structure of mortality. In order to make the cigarette measure comparable to previous estimates in the literature (and therefore relevant to instantaneous risks), it must be converted to represent the expected present value of living if the hazard is not consumed.

25/ That is, consumers are assumed to estimate the excess probability of death due to smoking at any age to be $P_e = dA\exp(K/Age^2)$ where d is a scaling factor that reflects aggregate beliefs about the magnitude of the harm from smoking.

26/ For example, see Olson and Bailey (1981). In essence, positive demand for productive capital suggests that the rate of interest must exceed the rate of time preference; the same inference is supported by the empirical fact that consumption appears to increase with age.

27/ More precisely, individuals were asked to categorize the statement "A 30 year old person reduces his life expectancy if he smokes at least one pack a day." Responses were "Know it's true", "Think it's true," "Don't know if it's true," "Think it's not true," and "Know it's not true." Responses in the first two categories were considered affirmative. Those in the last two categories were considered negative.

28/ For instance, in the same survey, only 2.9% of the population and 5.1% of smokers denied that smoking causes lung cancer, a widely acknowledged fatal disease. Moreover, aggregate data shows that while 40 percent of smokers may say that smoking does not cause early death, only seven percent of smokers persist in smoking non-filtered cigarettes. (see J. P. Maxwell).

29/ The results remained essentially unchanged when the zero-cost response were assigned to the 0-1 range. These assignments were done on the basis of information reported in note 28/.

30/ In particular, the density function for the shift M is now

$$h(M) = \int_0^{\text{Max } b} f(v(M,b))R(b)n^*E(T)/(n^*-(bv/n^*E(T)ek)^{1/(e-1)})b\ db$$

where f is the density of individual values of life, v(M,b) is the value of life corresponding to M and b, and R is the Roper density for the belief parameter b. The corresponding density function for nicotine choices is

$$J(n) = \int_0^{Max\ b} f(v(n,b))R(b)(e(e-1)kn^*E(T)(n^*-n)^{e-2}/b)db.$$

The solution algorithm again requires iteration on the parameters of the value of life distribution as well as the nicotine taste parameters e and k. However, because of the joint determination of the shift M, the model generated densities for both M and n must be compared against the market generated densities. The minimum sum of squared differences is again used as a solution criterion.

31/ See note 3/.

32/ Hamilton (1972), Ippolito et. al. (1979), Klein et. al. (1981) and Warner (1977) have estimated the effects of information disclosure on per capita cigarette consumption. While these studies have used different methodologies and covered somewhat different time periods, their results, when extrapolated to common years, have been remarkably similar.

33/ These results remained virtually unchanged when estimated using the Cochrane-Orcutt technique to correct for serial correlation.

34/ The correlation between nicotine and tar (the other major index of harm) is very high (.92 using 1975 Federal Trade Commission data).

35/ It is arguable that the nicotine-type cigarette distribution would have naturally spread over time to include milder cigarettes either to attract a wider population of smokers or to satisfy the demands of (generally lower nicotine smoking) females who comprised a larger proportion of the smoking population over time. By assuming continuation of the point distribution to 1980, the entire reduction in the mean and the corresponding increase in the spread of the nicotine-type cigarette distribution is attributed to consumers' reaction to health information; hence, estimates of the value of life are biased upward for this reason.

36/ Consistent nicotine measurements by brand have been available from the Federal Trade Commission since 1967. Since brand shares are also available from Maxwell, reductions in nicotine consumed per cigarette can be separated into within brand reductions and across brand switches for the post 1967 period. Using 1967 FTC nicotine measurements, the effects of brand switching on nicotine content over the period 1952 to 1967 can also be readily calculated. Assuming that within brand reductions in nicotine content over this period took place in the same proportion to brand switching as they did after 1967, the actual nicotine content per cigarette in 1952 (and prior years) is put at 1.49 milligrams.

37/ More particularly, the Center for Disease Control survey in 1975 described the smoking history of survey participants. Thus, adjusting the data to account for the higher death rate of smokers, it is straightforward to construct smoking participation rates by age and year for the ages 21-47 and the years 1947-1975.

38/ Elsewhere, it has been found that the probability of smoking may be independent of income and price (see Ippolito et. al.). This does not imply that smoking intensity levels are independent of price and income.

Table 1

Available Evidence about Smoking Behavior
With and Without Disclosures, 1980

Smoking Behavior	Without Information	With Information
Per Capita Cigarette Consumption (Packs per year; 18 years old and over)	386*	195
Percent of Population Smoking (18 years old and over)	54.2*	32.5
Price Elasticity of Cigarette Demand	-.48*	-.48*
Nicotine Content Per Cigarette Smoked (Milligrams)		
Mean	1.49*	.996
Standard Deviation	0	.34

* The numbers not marked by an asterisk are data reported by or calculated from published sources in 1980. The numbers marked by an asterisk are estimates of what smoking behavior would have been in 1980 if cigarette-health disclosures had never been made available. For purposes of application, the nicotine content distribution that existed in 1980 was fit by a logistics equation. All data sources and estimations are provided in the Appendix.

Table 2

Range of Estimated Values of
One Year of Life Saved

Demand Shift 1/	Years Lost Per Pack 2/		
	2.0	3.5	5.0
$ .91	$12,649	7,327	5,142
$1.15	14,855	8,622	6,050
$1.28	16,008	9,237	6,507

1/ The range of demand shifts is determined by the 95 percent confidence intervals of underlying statistical estimates on quantity and smoking participation reactions to disclosures. In cases where several estimates were made, the largest standard errors found in any estimate were used.

2/ The cited life cost of smoking assumes daily lifetime consumption of a typical 1952-equivalent nicotine content cigarette.

Table 3

Estimates of the Value of Life

Discount Rate	Lower Bound Estimate	Best Estimate	Higher Bound Estimate
0	$179,970	$301,770	$560,280
.0125	196,678	331,465	618,220
.025	217,613	368,495	690,351
.050	294,502	503,132	950,426
Demand Shift	$ .91	$1.15	$1.28
Life Cost: pack a day habit (years)	5.0	3.5	2.0

Table 4

Results of the Roper Survey of Consumer Beliefs About the Life Expectancy Cost of Smoking 1980[1/]

Estimated Life Expectancy Loss From Smoking[2/] (Years)	Respondent Distributions		
	Total	Smokers (Percent)	Non-smokers
Zero	30.4	40.9	24.7
Less than 2	5.2	5.6	5.0
2 - 4	11.9	13.3	11.3
4 - 6	15.5	14.2	16.2
6 - 8	10.0	8.0	11.0
8 - 10	10.7	6.2	13.1
More than 10	4.6	2.7	5.6
Don't know how much [3/]	11.7	9.1	13.1
Total	100.0	100.0	100.0

1/ In 1980, the Federal Trade Commission asked the Roper Organization to include numerous smoking questions in their 1980 random survey. The survey included 1,005 individuals, including 339 smokers, reflecting the national smoking participation rate (see Appendix).

2/ Individuals were asked whether a 30 year old person reduces his life expectancy if he smokes at least one pack a day for life. If he answered in the affirmative, the respondent was then asked to reveal his estimate of the life expectancy cost.

3/ These individuals said they thought that smoking reduced life expectancy but were unable to assign a particular number of years to this loss.

Table 5

Value of Life Estimates When Health Beliefs Are Not Identical

	Distribution of Belief	Constant Beliefs
Fitted Value of Life Distribution		
Mean	$8,500	$6,950
Standard Deviation	6,000	7,415
Characteristics of Beliefs		
Mean (years)	4.3	4.3
Distribution	Roper	None

The calculations in this table correspond to the case where the individual demand shift distribution has a mean of $1.15; the assumed rate of time preference is zero. The iterative solutions are characterized by nicotine preference parameters equal to: e = 3 and k = 1.2.

Table 6

Effects of Health Information on Cigarette Consumption

Dependent Variable	t	$D53/(1-e^{dT53})$	D64 T64	P	y	R^2	D.W.
1. Per Capita Consumption (n=46)	.557 (8.97)	-.171 (7.33)	-.0317 (20.35)	-.733 (7.64) [-.48]*	.627 (7.29)	.988	1.26
Dependent Variable	**t**	**D53**	**D64 $(T64)^2$**	**log P**	**y**	**R^2**	**D.W.**
2. Smoking Partici-pation Rate (n=28)	.049 (5.02)	.028 (2.64)	-.0018 (8.40)	-.059 (.83)	-.066 (.86)	.974	2.14
3. Smoking Partici-pation Rate (n=28)	.023 (3.33)	.033 (2.54)	-.0022 (21.57)			.960	1.38

The constant terms in these regressions are not reported. Numbers in parenthesis are t-statistics. The equations were estimated using ordinary least squares; the results remained virtually unchanged when estimated by the Cochrane-Orcutt method to reduce serial correlation. For purposes of calculating the bounds for value of life estimates, the larger standard errors found in either equation 2 or equation 3 or using OLS or Cochrane-Orcutt estimates were used.

* Number in brackets is the price elasticity of demand calculated at price 65.6¢ per pack (the average price of cigarettes in 1980).

Figure 1

Pre and Post Information Demand When

The Optimal Quality of Cigarette Changes

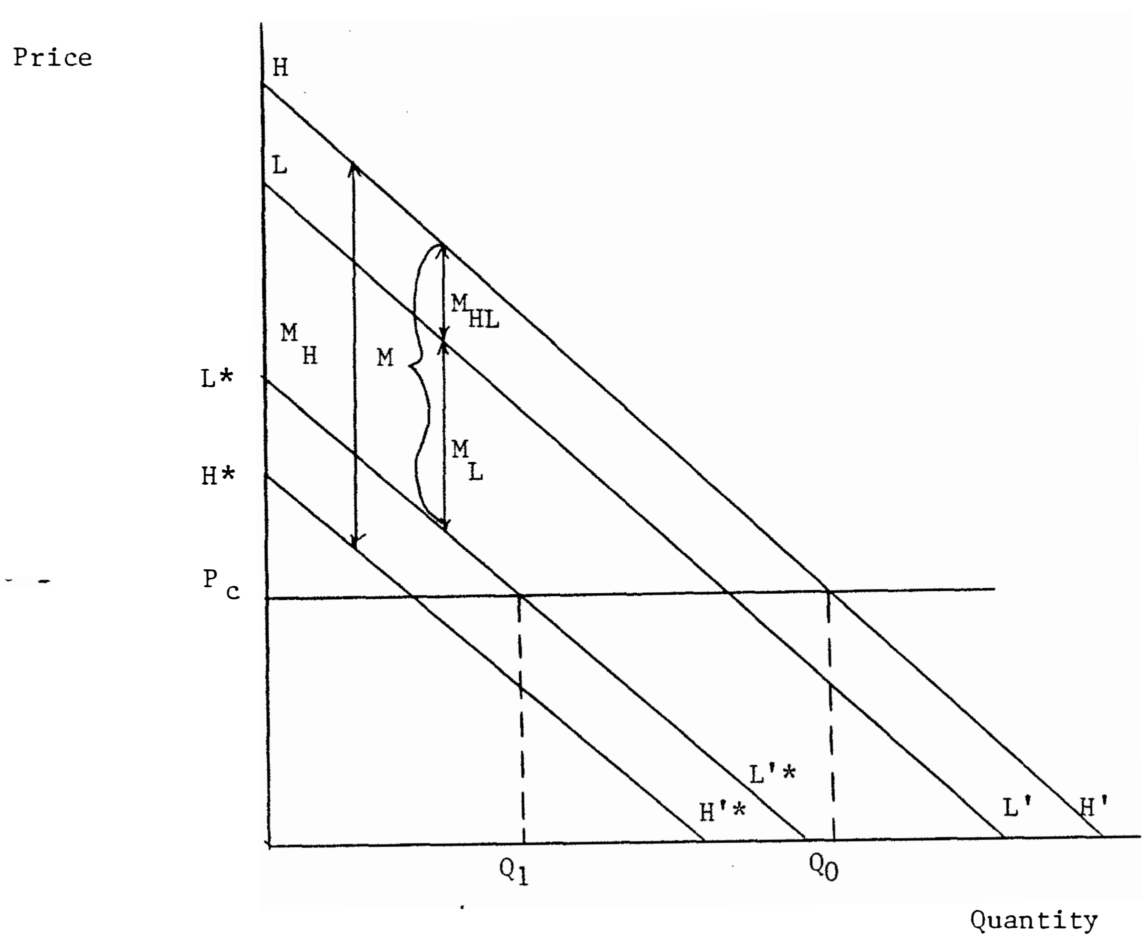
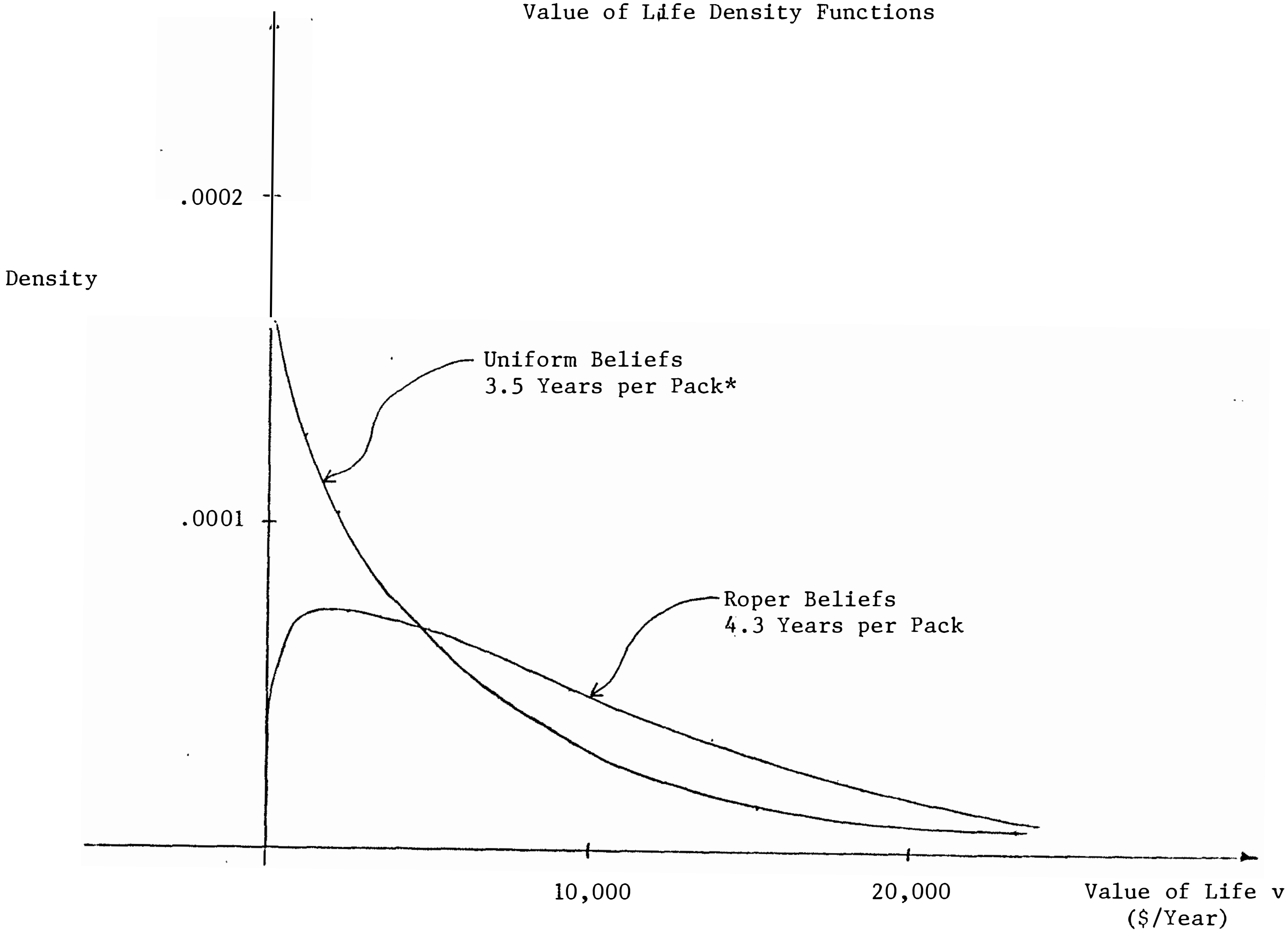


Figure 2

Value of Life Density Functions



* The density function for uniform beliefs equal to 4.3 years is very similar to the 3.5 year function.

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