THE SOCIAL COSTS OF CHRONIC HEART AND LUNG DISEASE

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INTRODUCTION

To value a program that reduces the probability of contracting a chronic disease, one would like to know what a person who does not have the disease would be willing to pay to reduce his probability of getting it. The sum across individuals of these willingnesses to pay, plus the expected costs of the disease that are not borne by these individuals, comprise the theoretically correct measure of social benefits from reducing incidence of the disease.

In this paper we measure the medical costs and lost productivity associated with various chronic heart and lung diseases. Our justification for focusing on these components of the social cost of illness is that medical costs and lost earnings are often not borne by individuals themselves and, hence, are unlikely to be reflected in willingness to pay figures. Therefore, they must be added to willingness to pay estimates to compute the total benefits of reducing the incidence of a disease.

Effects on Earnings

Our estimates of the effects of chronic illness on labor force participation and on earnings differ in two respects from those available in the literature (Bartel and Taubman, 1979; Salkever, 1985). First, our dataset--the Social Security Survey of Disabled and Non-Disabled Adults--allows us to distinguish the effects of individual diseases (e.g., emphysema, chronic bronchitis) rather than disease categories (chronic respiratory illness).[1] As one might expect, there is significant variation in the effects of individual diseases within broader categories: Emphysema, for example, has a large negative effect on earnings whereas chronic bronchitis does not. Hypertension has no significant effects on

1. The diseases studied are: allergies, asthma, chronic bronchitis, emphysema, other chronic lung disease, arteriosclerosis, heart attack, hypertension, other chronic heart disease and stroke.

probability of participation or on earnings, whereas a heart attack occurring between 45 and 54 reduces both.

Second, we examine how the effect of each disease varies with age of onset and duration. It is generally believed (Bartel and Taubman, 1979) that, other things equal, a person is more likely to participate in the labor force at any age the earlier in life he contracts a chronic disease. The argument is that the benefits of making adjustments to the disease (retraining, changing occupations) are larger the earlier in life the disease begins. Thus, the earlier the age of onset the more likely it is that adjustments will be made. It is not, however, clear that the human capital argument applies to the diseases examined here, most of which are contracted later in life. Since one seldom witnesses changes in occupation after age 45 it is unlikely that small variations in age of onset matter after this age. Indeed, age of onset may have a positive effect on participation if a disease is more serious when contracted at an earlier age.

It is also of interest to see how the duration of a disease alters labor market behavior. For two persons who contracted emphysema at age 45, are effects on earnings greater for a person currently 50 or for a person currently 60? Holding age of onset constant, this is equivalent to asking whether the disease has a greater effect on participation and earnings when one has had the disease for five years or for fifteen years. One might hypothesize that the longer one has had a disease the longer he has had to adjust to it; hence, labor market effects should diminish with duration. On the other hand, for progressive diseases, e.g., emphysema, the longer one has had the disease the more serious it is likely to be.

We find that the tendency of chronic disease to reduce labor force participation and earnings does not increase with age of onset. Indeed, for emphysema, heart attack, arteriosclerosis and stroke, an age of onset between 45 and 54 significantly reduces the probability of working at all future ages, but an age of onset between 55 and 65 does not. It might seem that this result occurs because people who contract a disease earlier will, on average, have had it for a longer time than persons who contracted it

later in life. For emphysema this appears to be true. When duration is held constant, it is having the disease for 6 or more years that affects labor market behavior rather than contracting it at age 45. For heart attack, arteriosclerosis and stroke, however, the duration of the disease, holding age of onset constant, has no effect on participation.

Medical Costs

Our estimates of medical costs, which come from the National Medical Care Expenditure Survey (NMCES), have two advantages over existing estimates of medical expenditures (National Heart, Lung and Blood Institute, 1982; Hartunian et al., 1981). The National Heart, Lung and Blood Institute allocates aggregate costs, such as hospital costs and doctor costs to diseases based solely on a disease's proportion of total activities, e.g., hospital days and total doctor visits, respectively. This approach has two shortcomings: (1) it assumes that the average cost of, say, a hospital day or doctor's visit is the same for all diseases, and (2) it does not allow one to examine the distribution of medical costs per person. An alternative "engineering" approach is to multiply the number of hospital days or doctor visits attributable to a condition by the typical price for a hospital day or typical price for a doctor visit for that condition (see e.g., Freeman (1976)). This approach circumvents the first objection raised above but not the second.

By using individual data on medical costs, collected over a one-year period for over 40,000 persons, we are able to examine the distribution of medical costs per person by disease. Our most interesting results pertain to the size distribution of medical costs. For the five diseases whose medical costs we study--bronchitis, emphysema, hypertension, ischemic heart disease and non-specific heart disease--the distribution of annual costs per person is highly skewed. For emphysema, ischemic heart disease and non-specific heart disease median expenditures are less than one-tenth of mean expenditures. For bronchitis and hypertension median expenditures are about one-fourth of mean expenditures.

Because NMCES contains information on source of payment, it is also possible to see to what extent individuals and their families bear the

medical costs of these diseases. For emphysema, ischemic heart disease and non-specific heart disease only about 10% of aggregate medical costs are borne by patients' families. The percentages are somewhat higher for bronchitis (34%) and hypertension (23%). The percent of cost borne by the patient's family differs, however, by size of cost. As noted above, the majority of persons with the diseases studied here incur small annual medical expenses. Averaging across individuals, the fraction of medical costs paid for by one's family is 2/3 for hypertension and bronchitis and half for emphysema, ischemic heart disease and non-specific heart disease. This implies that, on average, individuals (or their families) pay a higher fraction of small medical expenditures than of large ones.

THE EFFECT OF CHRONIC ILLNESS ON LABOR FORCE PARTICIPATION AND EARNINGS

The Model

In modelling the effects of various diseases on earnings it is standard practice (Bartel and Taubman, 1979; Mitchell and Butler, 1986) to distinguish the effects of each disease on participation from its effects on earnings given that one participates. Debilitating diseases such as emphysema and stroke may force a person to drop out of the labor force because he is physically unable to work, or may reduce earnings to the point where they fall below the reservation wage. If a person continues working he may curtail hours (if free to do so) or suffer a drop in pay because he changes jobs or because his productivity falls. This implies a drop in earnings, conditional on working.

The decision to participate, and earnings, conditional on participation, constitute a two-equation system. The individual participates if the decision function, I_t, is non-zero. Earnings, Y_t, are observed only if the individual participates.

$$I_t = Z_t\delta - e_t \qquad \text{Participation decision} \qquad (1)$$

$$\text{Participate if } I_t \geq 0,$$

$$Y_t = X_t\beta + u_t \qquad \text{Earnings in labor market} \qquad (2)$$

Y_t observed if $I_t \geq 0$

Y_t not observed if $I_t < 0$.

Equation (1) can be viewed as a reduced-form equation that results from comparing the utility received from income and leisure, conditional on working, with the utility received from income and leisure given that the individual does not work. If income and leisure in each state are replaced by their exogenous determinants, one obtains equation (1).2

Because earnings in (2) are observed only for working persons, estimation of (2) involves a classic selectivity problem: persons for whom earnings data are available are in the lower tail of the error distribution in equation (l). As long as the errors in equations (1) and (2) are correlated, applying least squares to (2) results in inconsistent parameter estimates since $E(u_t | Z_t\delta \geq e_t) \neq 0$.

To obtain consistent estimates of this system we follow the two-stage approach outlined by Lee (1983) [see also Maddala (1983)]. We assume that the error term in the participation equation has a logistic distribution $F(e_t) = 1/[1+\exp(-Z_t\delta)]$, and estimate a logit model of labor force participation. The error term e_t can be transformed to an error term e_t^* with a standard normal distribution,

$$e_t^* = J(e_t) = \Phi^{-1}(F(e_t)),$$

where Φ^{-1} is the inverse of the standard normal distribution function. Assuming that e_t^* and u_t are bivariate normally distributed with correlation coefficient ρ and $V(u_t) = \sigma^2$, expected earnings are a linear function of X plus a term ϕ/F that represents the density of e_t^* conditional on working,

$$E(X_t\beta + u_t | e_t \leq Z_t\delta) = X_t\beta + \sigma\rho\phi[J(Z_t\delta)]/F(Z_t\delta) + \quad (3)$$

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2. This implies that all variables entering (2) should enter (1).

Applying OLS to (3) yields consistent estimates of the parameters β and $\sigma\rho$.[3]

The Data

The Sample. The data used to estimate our model come from the 1978 Social Security Survey of Disability and Work (U.S. Department of Health and Human Services, Social Security Administration, 1981). The survey, which was designed to examine issues relating to eligibility for disability benefits and the effects of disabilities on labor force participation, consists of two samples, a stratified random sample of 6,853 persons from the 1976 Health Interview Survey, and a sample of 4,886 persons from the population of recipients of Social Security Disability Insurance who were declared eligible for benefits no earlier than 5 years before the survey. Our sample consists of 2,218 men between the ages of 18 and 65 from the Health Interview Survey portion of the Social Security Survey.[4]

Earnings Equation. To avoid transitory fluctuations during the survey week, earnings are measured as wages and salaries received from all jobs during 1977. (All earnings are measured in 1977 dollars.) The independent variables entering the earnings equation X_t, are listed in Table 1. Earnings are assumed to depend on education (measured by a series of dummy variables), experience (proxied by a series of age dummies), experience squared, marital status, family size, race, locational dummies and the health variables described below and in Table 2.

Labor Force Participation Equation. As with earnings, participation is defined based on behavior throughout the 1977 calendar year. An individual is considered to have been in the labor force if he worked 30 or more weeks during the 1977. Men who did not work at all during 1977 are classified as not participating in the labor force. Men working between

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3. The two-stage estimation procedure, including asymptotic standard errors (Maddala, 1983), was programmed by the authors using the SAS matrix language.

4. There are a total of 2,626 men between 18 and 65 in the HIS portion of the Social Security survey. 408 of them were eliminated because they appeared to change labor force status during 1977, the year for which participation and earnings were measured.

one and 29 weeks were eliminated from the sample on the grounds that these persons were either students or changed labor force status.

Since the decision to participate in the labor force is made by comparing the utility of income and leisure when in the labor force with income and leisure when out of the labor force, the variables in Z_t should include all those entering the earnings equation, plus variables that would affect income conditional on not participating, and variables that would affect the utility of leisure time. The only such variables available in the survey that are not included in X_t are (1) whether the individual is aware of Social Security disability benefits and (2) whether the individual is a veteran, both of which might affect income received if the individual did not participate. A third variable included in Z_t to capture motives for working is the size of the respondent's debt.

Health Variables. The survey contains two types of information about chronic illness. Respondents were asked whether they had ever been diagnosed by a doctor as having any one of the 35 chronic diseases listed in Table 2, as well as when the disease first began to bother them (age of onset). They were also asked whether they were functionally limited by any of the diseases. Functional limitation questions include whether the respondent had difficulty walking, climbing stairs, lifting heavy objects, etc. Respondents were also asked whether they experienced symptoms such as pain, fatigue, swelling and shortness of breath.

In both the earnings and participation equations the severity of chronic disease is measured by dummy variables that indicate the presence of a chronic condition. Pleasures of functional limitation, while possibly useful as indicators of the severity of disease, are not associated with specific diseases and, hence, cannot be used to measure the severity of individual diseases.[5]

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5. In addition to collecting these measures of functional limitation, the survey also asks respondents if they "have a disability that limits the type or amount of work [they] can do?" This variable, which is included in addition to the chronic disease dummies in Mitchell and Butler's (1986) analysis of the labor market effects of arthritis, was excluded from our analysis for two reasons. First, the answer to this question is not an exogenous measure of health but reflects the

Footnote 5 continued on next page

In measuring the effect of particular diseases on participation and on earnings we would like to distinguish effects by age of onset and by duration of the disease. The extent to which this is possible depends on the disease studied. Table 3 gives the distribution of age of onset for persons in our sample for each of the 10 respiratory and circulatory diseases studied. In our sample few cases of emphysema, arteriosclerosis, or stroke occur before age 45. For this reason these diseases are represented by only two age of onset dummies indicating that the disease was contracted between the ages of 45 and 54 or between the ages of 55 and 65.

Chronic bronchitis and other chronic lung disease occur earlier in life than emphysema; however, the small numbers of persons in our sample with these conditions restrict us to only two age of onset categories for" each disease: before age 45 and after age 45. Allergies, asthma, heart attack, hypertension, and other chronic heart disease occur frequently enough and early enough in life that we can distinguish between 3 and 5 age of onset categories for each disease, as indicated in Table 2.

We have attempted to distinguish between duration of disease and age of onset only for those diseases that appeared to have a significant effect on labor force participation when age of onset alone was measured.[6] These included emphysema, arteriosclerosis, heart attack, stroke and other heart disease. Each disease was significant only when age of onset was 45 or older. The fact that these diseases occur later in life, together with a maximum sample age of 65, means that we can distinguish only two duration categories: persons who have had the disease 0-5 years and persons who have had the disease 5-10 **years.**[7]

Footnote 5 continued from previous page
decision to stop/continue working. Second, the variable may capture effects of multiple diseases that we wish to capture using disease-specific dummies.

6. Throughout the paper "statistically significant" means significant at the 5% level, one-tailed test.

7. Chronic bronchitis beginning between ages 25 and 44 significantly decreased the probability of labor force participation; however, there were too few persons who had had chronic bronchitis for more than 10 years to permit using additional duration dummies for this disease.

Results

Labor Force Participation. The more serious respiratory and circulatory diseases examined--chronic bronchitis and emphysema; arteriosclerosis, heart attack, stroke and other heart disease--significantly reduce the probability that a man participates in the labor force, other things equal. Table 4 presents coefficients obtained from the logistic participation equation for the respiratory and circulatory disease variables listed in Table 2. [The coefficients of other variables in the participation equation appear in the appendix to this paper.] The table indicates that the less serious diseases--allergies, asthma, other chronic lung disease and hypertension--have no significant effects on participation. To calculate the effect of each disease on probability of participation its coefficient must be multiplied by P(1-P), where P is the probability of participation. Since P = 0.670 for our sample, the coefficients in Table 4 imply that contracting emphysema between ages 45 and 54 reduces the probability of participating in the labor force by an average of 23.3 percentage points. Arteriosclerosis reduces probability of participation by 15.6 percent, while having a stroke between 45 and 54 reduces subsequent probability of participation by 57.3 percent.

What is somewhat surprising is the effect of age of onset on participation. For emphysema, arteriosclerosis, heart attack and stroke, an age of onset between 45 and 54 significantly reduces probability of working at all future ages, but an age of onset between 55 and 65 does not. Such a result runs counter to the standard argument that, the earlier the onset of a disability, the more likely it is that the individual will adjust to it by retraining and/or switching jobs. One reason that the standard argument may not apply is that, for the diseases studied here, a diagnosis at age 45 may indicate a more severe case of the disease than a diagnosis at age 60 (a heart attack at age 45 is often more devastating than a heart attack at age 60).

A second possibility is that for progressive diseases such as emphysema and arteriosclerosis, persons who contract the disease earlier will, on average, have had it for a longer time than persons who contract it later in life. To the extent that severity increases with the duration

of the disease, persons who have had the disease longer will be less likely to work.[8] The results in Table 4 may thus be due to the fact that age of onset is directly correlated with the number of years the individual has been bothered by the disease.

To test this hypothesis the age of onset categories in Table 2 were subdivided to distinguish duration of disease from age of onset. Persons with an age of onset between 45 and 54 were divided into two categories: those who had had the disease for 0-5 years and those who had had the disease for 6-10 years. For persons with an age of onset between 55 and 65 only the 0-5 year duration category was used.[9]

The estimated coefficients of the age of onset/duration dummy variables appear in Table 5. These coefficients suggest that controlling for duration alters the effect of age of onset only in the case of emphysema. For emphysema, when duration is held constant at 0-5 years, age of onset has no effect on participation. Having the disease for 6-10 years, however, significantly reduces the probability of participation. In the case of arteriosclerosis, heart attack and stroke, however, the main effect on labor force participation is caused by age of onset, with onset between 45 and 54 making participation less likely, and onset between 55 and 65 having no significant effect. These results suggest that the effect of age of onset and duration are, in general, disease-specific.

Earnings. The results for our earnings equations suggest that, for the respiratory and coronary diseases studied here, most labor market effects occur through reductions in participation rather than reductions in earnings. Table 6 presents coefficients of the disease dummies in an earnings equation in which diseases are distinguished by age of onset and,

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8. One could, of course, argue that persons with very severe cases of the disease die soon after diagnosis; hence duration may not measure severity.

9. Persons with an age of onset between 55 and 65 with duration greater than 5 years thus had a value of zero for all health dummies, as did persons without the disease.

in the case of emphysema, by duration.[10] The only respiratory and circulatory diseases studied that significantly reduce earnings are emphysema and heart attack. Having emphysema for 6-10 years reduces earnings by 65%. Having a heart attack between the ages of 45 and 54 reduces earnings by 45%.

The Magnitude of Expected Earnings Losses. The expected loss in earnings to a person who contracts a chronic disease is the sum of the effects of the disease on probability of participation, and on earnings, given that one participates. Specifically, the expected loss in earnings is the sum of the change in probability of participation times pre-illness earnings, plus the reduction in earnings caused by the disease times the post-illness participation rate, P_1,

$$\text{Expected Loss in Earnings} = \Delta P(\text{Earnings}_0) + P_1(\Delta\text{Earnings}). \quad (4)$$

This loss begins at age of onset and continues until the age that retirement would occur in the absence of the disease.

Tables 7 and 8 present estimates of the first term in (4), expected earnings losses due to non-participation. The effect of each disease on probability of participation, ΔP, is determined by multiplying the coefficient of the disease in the participation equation, δ_i, by P(1-P), where P is the probability of being in the labor force. Table 7 presents estimates of ΔP, the fraction by which pre-illness earnings are reduced due to non-participation. In the tablet P is estimated at each age from Bureau of Labor Statistics data on labor force participation rates (U.S. Department of Labor, Bureau of Labor Statistics, 1988). In Table 8 ΔP has been multiplied by average 1987 earnings of all male workers to produce annual earnings losses, by age, due to non-participation.

In both tables earnings losses due to increased probability of not working peak between 55 and 65, because P(1-P) is maximized in this

10. Because fewer chronically ill people appear in the earnings equation than in the participation equation it was necessary to eliminate certain age of onset categories from the earnings equations.

interval. The maximum annual expected reduction in earnings ranges from 15.5% for heart attacks to 57.1% for strokes. Bronchitis and emphysema each reduce expected earnings (through effects on participation) by at most 25%.

For emphysema, arteriosclerosis, stroke and other heart disease earnings losses due to reduced probability of participation constitute the total change in expected earnings. For emphysema and heart attack the second term in equation (4) must be computed. This term, in $1977, appears in Table 8 together with expected earnings losses due to non-participation.

Comparison with Previous Work. The only study of the labor market effects of chronic respiratory and circulatory diseases of which we are aware is Bartel and Taubman (1979). Using data from the NAS Twins Panel, Bartel and Taubman examine the effects of each of several disease groups on labor force participation and on earnings, conditional on participation. Unfortunately the diseases groupings used by Bartel and Taubman do not correspond exactly to the diseases used in our study. They combine bronchitis, emphysema and asthma into a single disease category (BRON), and heart disease and hypertension into another category (HH). The effect of each disease category, is examined for various ages of onset; however, emphasis is placed on diagnoses that occurred between 1962-67, when respondents were in their early forties. Because emphysema, arteriosclerosis and stroke are rare at this age, it is unlikely that BRON and HE capture these more severe diseases.

When they examine the effects of a diagnosis at age 40 on participation at age 50 Bartel and Taubman do not find any significant effects of respiratory or circulatory diseases on labor force participation. This is in sharp contrast to the results presented in Table 7, which indicate that chronic bronchitis, emphysema, arteriosclerosis, heart attack, stroke, and other heart disease reduce the probability of labor force participation between 6 and 57 percentage points. The difference in findings may be due in part to the relatively young age of their sample. The disease variable used in the participation equation represents the effects on participation at (mean) age 50 of a diagnosis

that occurred at (mean) age 40. For the diseases we study the most significant effects on participation correspond to an average age of onset of 50.

Regarding effects on earnings, Bartel and Taubman find that a diagnosis of respiratory illness (BRON) at age 40 reduces earnings by 25% at age 50 and that heart disease/hypertension (HH), diagnosed at age 40, reduces earnings by 8.5% at age 50. By contrast, we find that having emphysema for at least 6 years reduces earnings by an average of 65% for persons who continue working. The corresponding reduction in earnings due to having a heart attack between 45 and 54 is 45%. We thus find greater effects on earnings than do Bartel and Taubman, but for more narrowly defined diseases. The difference between our results and theirs reflects the fact that their disease categories include less severe diseases, such as bronchitis and hypertension, as well as more debilitating ones.

MEDICAL EXPENDITURES AND SERVICES UTILIZATION

The medical costs of a chronic disease to society are the costs of the detection, treatment, and rehabilitation of the disease, as well as a portion of research, training, and facilities costs. In this section we present measures of medical expenditures for individuals for five target diseases: hypertension, ischemic heart disease, non-specific heart disease, chronic bronchitis, and emphysema. These measures were computed from self-provided cost of treatment data for persons in the 1977-78 National Medical Care Expenditure Survey (National Center for Health Services Research, 1981).

There are three reasons why our measures of medical expenditures do not measure the true social costs of medical treatment. First, medical expenditures are computed using market prices, which may not reflect marginal productivities due to the absence of competition in the market for medical services. Second, because the data are specific to individuals with chronic diseases, the costs of detection are not included. In addition, because medical care providers are a minor source of research and medical training, these cost components are likely to be greatly underestimated (if included in overhead charges) or ignored completely.

The National Medical Care Expenditure Survey

To estimate the medical costs of chronic respiratory and heart disease we used the 1977-78 National Medical Care Expenditure Survey (NMCES). NMCES presents data on health care utilization and expenditures for approximately a one year period for 14,000 households (40,320 persons) selected randomly from the civilian noninstitutionalized U.S. population. Each of these households was provided with a calendar diary for recording their use and cost of medical services. Each was interviewed six times over this period, with responses in prior periods provided to the household for verification.

Each time a person in the NMCES suffered an activity limitation, disability day, visited or called a doctor, vent to the hospital or purchased medication a record was created for an illness episode. Information on the number and cost of illness episodes and on the cause of each illness episode comes from the household survey. Medical costs are thus self-reported costs.[11] The diseases associated with each illness episode were reported by households, and translated into ICDA codes by interviewers.

The five respiratory and circulatory diseases we examine, their ICDA codes, and the number of persons reporting episodes involving each condition appear in Table 9.

Allocation of Medical Costs Among Multiple Conditions

To calculate the costs associated with a target condition one must add the costs associated with the condition across all illness episodes. This would pose no problem if all episodes of illness were associated with only a single disease. If, however, an illness episode is associated with more

11. To check on the accuracy of these costs, the household survey was supplemented by a survey of physicians and facilities that provided medical care to persons in the household sample period and by a survey of employers and insurance companies responsible for the health insurance coverage of responding households. A close correspondence was found between reported and actual costs.

than one condition, the cost of the episode must be allocated among conditions.

Table 10 indicates the extent of the joint cost allocation problem. The table indicates that of the 3,479 persons with at least one episode of hypertension, 71% (2,476) had episodes that involved hypertension alone. [In the language of NMCES an episode involving only a single condition is a “simple” episode.] For these persons the problem of cost attribution does not arise. Thirteen percent of persons (426 persons) with hypertension episodes have "related to" episodes--episodes that involve hypertension and some other condition. In these cases the respondent attempted to allocate costs among the related conditions; however, in cases where no attribution was possible, for example, the case of hospital room charges, the costs were duplicated for each condition. “Same as” episodes, involving 7% of all persons with hypertension, mean that the individual attributed the episode to hypertension and a condition that was the “same as” hypertension-- although it was assigned a different ICDA code. In this case no allocation of costs among the multiple conditions is possible; instead, the total costs of the episode are associated with each condition. “Same as " episodes thus lead to double counting of medical costs, and “related to” episodes may involve some double counting.

The number of persons with “multiple episodes" are found by subtracting those with ’single episodes from the total (e.g., for hypertension, 314 persons had multiple episodes). In general, persons with more than one episode involving the same disease have other than "simple” episodes that may involve double-counting problems.

Results

Magnitude of Expenses, by Disease. Table 11 shows the frequency distribution of annual medical expenses for each of our target diseases, as well as mean and median expenses. [All figures are in 1977 dollars.] As one would expect, the highest average expenditures are associated with ischemic heart disease ($1256) and non-specific heart disease ($1041). Emphysema is associated with a mean expenditures of $633. The average

annual costs of hypertension and bronchitis are considerably less: $216 and $97, respectively.

In each case the distribution of annual expenses is highly skewed: median expenses are one-quarter of mean expenses for bronchitis and hypertension and approximately one-tenth of mean expenditures for emphysema, ischemic heart disease and non-specific heart disease. For all diseases but ischemic heart disease at least half of all persons have annual expenditures of $75 or less. [For ischemic heart disease 41% of all persons have annual expenditures of $75 or less.]

Categories of Expenses. Table 12 shows how expenditures are distributed across categories for each disease. NMCES allocates expenses to three major categories: medical contacts (primarily doctor visits), hospital expenses, and drugs. There are several minor categories that are omitted from the table.

As would be expected, hospital expenses are the largest category of expenses for all conditions, even when people with no hospital expenses are included in the averaging computation. The maximum hospital expenses per person exceed $20,000 for the heart diseases and are in the $10,000 range for the other target diseases. Expenses on medical contacts are the next largest category of expenses for all conditions.

Comparison With Other Studies. The NHLBI (1982) estimates annual expenditures on chronic bronchitis and emphysema using the “top-down” approach described above while Freeman et al. (1976) use an engineering approach with aggregate data to estimate annual expenditures on emphysema. Table 13 provides the NHLBI and Freeman estimates of total and per person expenditures adjusted to 1977 dollars using the medical price index.

The NHLBI estimates of expenses per case, at $118 and $102 for chronic bronchitis and emphysema, respectively, contrast sharply with ours, at $97 and $633. Nevertheless, because of the top-down nature of the NHLBI approach, their estimates may differ from ours if different estimates of disease prevalence are being used. In fact, the NHLBI prevalence estimates

for these diseases (which are taken from the Health Interview Survey (HIS)) are 3.5 and 1.0 percent of the civilian, noninstitutionalized population of the U.S. in 1979 (216 million people) for chronic bronchitis and emphysema, respectively. Our estimates of prevalence, which are conditional on the occurrence of some medical event (i.e., a restricted activity day, some cost incurred, or some service used (including a phone call to the doctor)), are far lower -- 1.1 and 0.5 percent for chronic bronchitis and emphysema, respectively, for 1977.

The underestimate of prevalence implied by this conditionality implies that our sample would under-represent, relative to the NHLBI, people with zero medical costs. This implies, in turn, that the NHLBI estimate of expense per case should be lower than ours. Instead, the NHLBI estimate for chronic bronchitis, the disease for which the highest proportion of sufferers in our sample has zero costs, actually exceeds our estimate.

Freeman et al, using data on health care utilization and average prices for 1970, estimate expenses on emphysema in 1977 dollars of $233.5 per case annually. These estimates are over double those of the NHLBI but still are far lower than ours.

Sources of Payment. NMCES provides information on five sources of funding for medical expenses: family, medicaid, medicare, personal insurance, and other. In addition to being of intrinsic interest, information about sources of funding suggests the extent to which medical costs are likely to be internalized in willingnesses to pay to avoid disease. In theory, willingness to pay should take into account the medical costs of the condition paid for by the family, but not those costs borne by others. Thus, the portion of expenses paid by others should be added to the bid as part of the social cost of each of the target conditions.

Table 14 identifies these funding sources by condition for males 20 years of age and older, the group to which our labor market analysis applies. For each disease the second row of the table gives the percent of total costs paid for by each source. Even for hypertension and bronchitis,

the least serious diseases studied, families pay a minority of total costs, 23% and 34%, respectively. For emphysema and the heart diseases families pay less than 15% of total costs. What are the most important sources of funding? Personal insurance is the most important source of funding for ischemic heart disease (46 percent), reflecting the high proportion of expenses for the hospitalization component and the high degree of coverage afforded this type of expense by health insurance plans. The insurance share for emphysema is large (28 percent) for much the same reason. Coverage for non-specific heart disease, the condition with the least family funding, is not dominated by insurance. Rather, because the population with this condition tends to be older than that for ischemic heart disease, the largest funding share comes from medicare (36 percent). Finally, it is curious that medicaid funds less than one percent of expenses for ischemic heart disease while funding from 7 to 17 percent of the expenses for the other target conditions.

Although a minority of total medical costs are paid for directly by patients and their families family funding is the q most important source of payment for a majority of patients. This is because most patients incur small expenses (see Table 11) and families bear a larger percent of small expenses than of large expenses. For each disease the third row of Table 14 computes for each individual the percentages of funding received from various sources and then averages these percentages across individuals for each source. As can be seen, the average percentages for the family source (in brackets) are much higher than the aggregate percentages for the family source (in parentheses), the former ranging from 52 to 70 percent, while the latter ranges from 13 to 36 percent. This difference implies that relatively large numbers of people have episodes with small expenses that they pay for themselves. This may reflect deductibility clauses, the exclusion of drugs from coverage for some policies, or other factors.

Age Distribution of Expenses. To permit comparison of the labor market effects of chronic respiratory and circulatory diseases with medical costs, Table 15 presents average medical costs for males, by age. Mean annual expenses appear generally to increase with age, up to the ‘60’s or

70’s for bronchitis, emphysema and hypertension. Expenses for those with heart disease (heart attacks), however, peak in the ‘40’s.

A comparison of average medical expenses with the labor market effects of each chronic disease (see Table 8) suggests that the labor market costs of chronic respiratory and circulatory diseases are generally greater than the medical costs. Exceptions to this result are hypertension, which has no effect on labor force participation or on earnings, and heart disease before the age of 45, which also appears to have no significant labor market effects.

Table 1. Non-health Variables Entering Earnings and Participation Equations

	Mean	Standard deviation	Maximum	Minimum
Earnings, 1977*	14,362.	77045.	50000.	0
In labor force, 1977	0.670		1	0
Married[a]	0.718	0.45	1	0
No. in household[a]	3.294	1.732	15	1
No. children < 5[a]	0.190	0.512	5	0
No. children 5-18[a]	0.670	1.174	8	0
No. children > 18[a]	0.184	0.482	3	0
Age dummies:				
18-24	0.141	0.348	1	0
35-44	0.174	0.379	1	0
45-54	0.222	0.416	1	0
55-65	0.261	0.440	1	0
Highest educ. level:				
Elementary school	0.193	0.394	1	0
High school	0.487	0.500	1	0
College	0.229	0.421	1	0
Non-white	0.124	0.330	1	0
Regional dummies[a]:				
Northcentral	0.265	0.441	1	0
South	0.335	0.472	1	0
West	0.178	0.383	1	0
Lives in Urban Area[a]	0.679	0.467	1	0
$(\text{Age}-16)^2$	888.25	730.23	2401	4
Veteran	0.452	0.498	1	0
Aware of disability benefits	0.407	0.491	1	0
Debt[a]	2116.9	8858.00	200800	0

*Average based on 1486 persons in labor force
[a]Measured as of interview date

Table 2. Health Variables in Earnings and Participation Equations

Each of the following variables assume a value of 1 if the respondent contracted the disease at the age indicated and a value of 0 otherwise:

RESPIRATORY AND CIRCULATORY DISEASES

	Age of Onset Categories (Sample Size)			
Allergies	0-17 (35)	18-34 (37)	35-65 (18)	
Asthma	0-17 (40)	18-34 (14)	35-65 (19)	
Chronic Bronchitis	25-44 (18)	45-65 (21)		
Emphysema	45-54 (49)	55-65 (23)		
Other Chronic Lung Dis.	18-44 (17)	45-65 (26)		
Arteriosclerosis	45-54 (55)	55-65 (24)		
Heart Attack	25-44 (28)	45-54 (57)	55-65 (42)	
Hypertension	25-34 (57)	35-44 (79)	45-54 (148)	55-65 (66)
Other Chronic Heart Disease	0-34 (23)	35-44 (34)	45-54 (51)	55-65 (22)
Stroke	45-54 (17)	55-65 (20)		

OTHER CHRONIC DISEASES	**Sample Size**
Arthritis or rheumatism	367
Other trouble with back or spine	296
Deformity of foot, leg, arm, hand	228
Nervous or emotional problems	209
Deformity of back or spine	154
Deafness	133
Stomach ulcer	130
Diabetes	113
Hernia or rupture	92
Difficulty reading (with glasses)	86
Kidney stones or kidney trouble	76
Other chronic stomach trouble	64
Tumor, cyst or growth	52
Hissing arms, hands or fingers	46
Gallbladder or liver trouble	40
Paralysis	35
Alcohol or drug problems	25
Cancer	24
Epileptic seizures	24
Mental illness	20
Blindness	19
Thyroid trouble or goiter	18
Hissing legs or feet	14
Tuberculosis	7
Multiple sclerosis	6

Table 3. Distribution of Respiratory and Circulatory Diseases by Age of Onset

	Number of persons in sample with age of onset					
	0-17	18-24	25-34	35-44	45-54	55-65
Allergies	35	18	19	10	4	4
Asthma	40	5	9	7	9	3
Chronic Bronchitis	15	2	13	5	15	6
Emphysema	0	1	4	3	49	23
Other Chronic Lung Diseases	1	4	7	6	20	6
Arteriosclerosis	0	0	7	11	55	24
Heart Attack	2	0	5	23	57	42
Hypertension	12	23	57	79	148	66
Other Chronic Heart Disease	18	5	10	34	51	22
Stroke	1	0	2	2	17	20

Table 4. Effects of Chronic Diseases on Labor Force Participation by Age of Onset

	Age of onset	Coefficient	t-Ratio
Asthma	0-17	00093	0.22
	18-34	0.625	0.75
	35-65	0.093	0.16
Allergies	0-17	-0.061	0.13
	18-34	0.505	0.95
	35-65	-0.565	0.91
Chronic Bronchitis	25-44	-1.229	1.69
	45-65	-0.816	1.17
Emphysema	45-54	-1.053	2.55
	55-65	-0.683	1.21
Other Chronic Lung Disease	18-44	-0.218	0.29
	45-65	-0.528	0.95
Arteriosclerosis	45-54	-0.707	1.72
	55-65	0.134	0.26
Hypertension	25-34	-0.435	1.16
	35-44	-0.131	0.38
	45-54	0.189	0.78
	55-65	-0.112	0.34
Heart Attack	25-44	-0.463	0.94
	45-54	-0.720	1.94
	55-65	0.507	1.15
Stroke	45-54	-2.593	2.38
	55-65	-1.530	1.41
Other Heart Disease	0-34	-0.393	0.90
	35-44	-0.184	0.40
	45-54	-0.896	2.39
	55-65	-1.462	2.04

Table 5. Effects of Chronic Diseases on Labor Force Participation by Duration of Disease and Age of Onset

	Duration	Onset	Coefficient	t-Ratio
Asthma		0-17	0.017	0.04
		18-34	0.780	0.92
		35-65	0.029	0.05
Allergies		0-17	-0.040	0.09
		18-34	0.542	1.02
		35-65	-0.479	0.78
Chronic Bronchitis		25-44	-1.254	1.70
		45-65	-1.013	1.46
Emphysema	0-5	45-54	-0.230	0.35
	5-10	45-54	-1.299	2.04
	0-5	55-65	-0.370	0.62
Other Chronic Lung Diseases		18-44	-0.465	0.65
		45-65	-0.670	1.19
Arteriosclerosis	0-5	45-54	-0.389	0.57
	5-10	45-54	-0.252	0.41
	0-5	55-65	0.659	1.11
Hypertension		25-34	-0.418	1.12
		35-44	-0.151	0.44
		45-54	0.084	0.35
		55-65	-0.088	0.27
Heart Attack		25-44	-0.449	0.91
	0-5	45-54	-1.003	1.70
	5-10	45-54	-1.069	1.85
	0-5	55-65	0.371	0.79
Stroke	0-5	45-54	-1.503	1.25
	5-10	45-54	-7.551	0.38
	0-5	55-65	-0.900	1.06
Other Heart Disease		0-34	-0.352	0.81
		35-44	-0.165	0.36
	0-5	45-54	-1.119	1.75
	5-10	45-54	-0.007	0.01
	0-5	55-65	-1.273	1.73

Table 6. Effects of Chronic Diseases on Ln(Earnings) by Age of Onset

	Age of Onset	Coefficient	T-Ratio
Asthma	-	-0.232	1.020
Allergies	-	-0.061	0.318
Chronic Bronchitis	-	-0.023	0.065
Emphysema	0-5[a]	0.229	0.641
	6-10[a]	-1.038	2.009
Other Chronic Lung Disease		-0.511	1.294
Arteriosclerosis	45-54	0.279	0.680
	55-65	-0.624	1.510
Hypertension	25-34	0.207	0.916
	35-44	-0.041	0.188
	45-54	0.193	1.211
	55-65	0.311	1.167
Heart Attack	25-44	0.056	0.151
	45-54	-0.590	1.706
	55-65	-0.376	1.141
Stroke	-	0.843	1.386
Other Heart Disease	35-44	0.302	1.008
	45-54	0.055	0.165

[a]Denotes duration of disease rather than age of onset.

Table 7. Effect of Respiratory and Circulatory Diseases on Probability of Participation by Age of Onset

		Change in probability of participation at each age				
Disease	Age of Onset	25-34	35-44	45-54	55-65	65+
Chronic Bronchitis	25	-0.067	-0.067	-0.111	-0.288	-0.180
	45			-0.084	-0.218	0.136
Emphysema	45			-0.099	-0.256	-0.159
	45			-0.060	-0.157	-0.098
Heart Attack	45			-0.059	-0.155	-0.096
Stroke	45			-0.220	-0.571	-0.356
	55				-0.327	-0.204
Other Heart Disease	45			-0.075	-0.196	-0.122
	55				-0.324	-0.202

Table 8. Annual Change in Expected Earnings at Each Age Due to Various Chronic Diseases ($1977)

Disease	Age of onset	Annual Change Due to Reduced Probability of Participation (Change Due to Reduction in Earnings if Working)				
		25-34	35-44	45-54	55-65	65+
Chronic Bronchitis	25	$-870.2	$-1226.3	$-2229.1	$-4860.9	$-1680.4
	45			-1689.6	-3684.4	-1273.7
Emphysema[a]	45			-1978.4	-4314.3 (-10891.)	-1491.5 (-6044 .7)
Arteriosclerosis	45			-1210.6	-2639.9	-912.6
Heart Attack	45			-1197.7 (-8949. 6)	-2611.8 (-7515.8)	-902.9 (-4171.2)
Stroke	45			-4415.8	-9629.5	-3328.9
	55				-5511.0	-1905.2
Other Heart Disease	45			-1513.7	-3301.0	-1141.2
	55				-5455.6	-1886.0

[a] Effects on Earnings do not begin until duration is greater than or equal to 6 years.

Table 9. Sample size by condition, NMCES.

Disease	ICDA codes	Persons
Total		4789
Hypertension	401-404	3479
Ischemic heart disease	410-414	378
Non-specific heart disease	429	884
Chronic bronchitis	490-491	430
Emphysema	492	222

Table 10. Distribution of single vs multiple episodes types.

Disease	Total persons	Number of persons with single episodes: One simple	One same-as	One* related-to/ stand-alone	Percent with only one single episode
Hypertension	3479	2476	227	462	91.0
Ischemic	378	195	34	80	81.7
Non-specific heart	884	501	104	166	87.2
Chronic bronchitis	430	272	49	63	89.3
Emphysema	222	130	21	42	86.9

*In each of these cases there is only one ‘stand alone’ episode to analyze that is associated with our target disease.

Table 11. Frequency Distribution of Annual Expenses per Person, by Condition. Unweighted.

Total Expense ($1977)	Percentage of Sample in Each Expense Category				
	Bronchitis	Emphysema	Hypertension	Ischemic HD	Nonspecific HD
$ 0	17.4	20.7	6.7	9.0	12.9
0-25	36.3	23.0	21.8	15.9	19.2
25-50	19.8	7.7	19.2	10.3	11.5
50-75	8.4	5.4	13.2	5.6	6.8
75-100	4.7	4.5	8.7	6.3	5.1
100-150	5.1	8.6	11.2	9.5	7.0
150-200	1.6	4.1	5.5	6.9	4.6
200-300	3.0	5.4	5.1	9.3	7.6
300-400	0.7	1.8	2.4	2.6	3.2
400-500	0.5	0.9	1.2	2.4	1.6
500-750	0.9	2.7	1.3	2.4	2.5
750-1000	0.2	1.4	0.6	2.6	1.5
1000-1500	0.5	3.6	1.1	2.9	2.6
1500-2000	0.2	4.1	0.4	2.4	1.9
2000-3000	0.2	1.4	0.6	1.3	2.6
3000-4000	.	0.9	0.2	2.9	3.1
4000-5000	0.2	1.4	0.1	0.3	1.4
5000-10000	0.2	1.4	0.5	3.4	2.9
10000-20000	.	1.4	0.1	2.6	1.1
20000+	.	.	0.1	1.3	0.9
N	430	222	3479	378	884
Mean Expense	$96.74	$632.76	$215.79	$1257.55	$1041.26
Median Expense	$23.27	$42.63	$53.51	$116.26	$73.90

Table 12. Average Expenses Per Person By Disease and Category ($1977).

CONDITION	Expenses	Mean Expense	Std Dev	Maximum
Bronchitis (n=430)	Medical Contact	$38.87	$117.30	$1683.00
	Hospital	41.30	499.76	9635.00
	Drugs	14.65	44.60	605.27
	Total Expense	96.74	537.54	9712.00
Emphysema (n=222)	Medical Contact	72.06	179.13	1683.00
	Hospital	498.40	2073.30	18832.00
	Drugs	46.43	94.72	730.01
	Total Expense	632.76	2171.28	19563.78
Hypertension (n=3479)	Medical Contact	51.88	127.12	2854.89
	Hospital	111.65	1278.68	57940.00
	Drugs	41.62	55.89	970.45
	Total Expense	215.79	1377.29	60588.00
Ischemic HD (n=378)	Medical Contact	96.23	273.83	3977.33
	Hospital	1069.38	3653.32	35910.00
	Drugs	68.88	105.86	791.32
	Total Expense	1257.55	3831.66	36462.00
Nonspecific HD (n=884)	Medical Contact	82.45	220.92	4074.04
	Hospital	859.10	3479.98	49638.00
	Drugs	44.71	83.18	1094.67
	Total Expense	1041.26	3736.60	49743.00

Table 13. Medical Expenses on Chronic Bronchitis and Emphysema from the NHLBI (1982) and Freeman et al (1976). (1977 $'s)

	Hospital	Doctor	Drugs	Total
NHLBI				
Chronic Bronchitis (millions of $'s)	$285	$162	$432	$879
Per Person	(38.1)	(57.8)	(21.7)	(117.7)
Emphysema (millions of $'s)	152	48	19	219
Per Person	(71.0)	(22.5)	(8.7)	(102.1)
Freeman et al				
Emphysema (millions of $'s)	$174	$71	$59	$304
Per Person	(133.4)	(54.5)	(45.6)	(233.5)

Table 14. Funding Source by Condition for Males 20 Years of Age or Greater. Weighted.

	N[a]	Mean Expense[b]	Family	Medicaid	Medicare	Personal Insurance	Other
CONDITION							
Bronchitis	478447	$205.24	$69.01[c] (34%)[d] [65%]	$4.25 (2%) [1%]	$57.58 (28%) [4%]	$62.38 (30%) [25%]	$12.02 (6%) [4%]
Emphysema	766736	726.78	100.54 (14%) [51%]	96.62 (13%) [3%]	172.74 (24%) [12%]	165.93 (23%) [18%]	190.95 (26%) [13%]
Hypertension	6644806	268.87	60.96 (23%) [68%]	14.44 (5%) [3%]	94.03 (35%) [4%]	48.57 (18%) [16%]	50.87 (19%) [9%]
Ischemic HD	1184816	1739.77	180.77 (10%) [50%]	186.23 (11%) [4%]	287.79 (17%) [9%]	840.05 (48%) [28%]	244.93 (14%) [8%]
Nonspecific HD	2019627	1662.99	164.38 (10%) [51%]	72.77 (4%) [6%]	685.51 (41%) [12%]	493.92 (30%) [18%]	246.41 (15%) [13%]

[a]Complex Multiple Episode excluded (see text).

[b]Mean does not include observations reporting zero.

[c]Percentage of Mean Expense.

[d]Percentage of Expense by Source, Averaged Over All Individuals.

Table 15. Average Medical Expenses for Males, by Age. Weighted.

CONDITION	Age Group	N	Mean Expense	Std Dev	Maximum	Total Expense (millions $)
Bronchitis	0-9	438016	$59.59	$109.84	$626.45	$26.1
	10-19	160828	33.55	51.83	270.00	5.4
	20-29	89507	84.99	148.34	514.00	7.6
	30-39	60767	46.86	63.46	197.56	2.8
	40-49	65470	96.40	140.54	446.05	6.3
	50-59	67189	141.66	186.04	654.60	9.5
	60-69	125470	249.56	781.04	4251.16	31.3
	70-79	58254	485.20	2061.74	9712.00	28.3
	80-89	11790	60.22	51.86	116.00	0.7
	≥ 20	478447	180.94	841.34	9712.00	86.6
	Average	1077291	109.60	569.05	9712.00	118.1
Emphysema	40-49	50017	562.54	672.46	1647.00	28.1
	50-59	164485	884.41	2481.30	13535.82	145.5
	60-69	341324	371.82	1639.63	17615.01	126.9
	70-79	168861	580.66	2667.20	19563.78	98.1
	80-89	39177	1474.26	1585.82	4854.75	57.8
	90-99	2872	2.19	0.00	2.19	0.01
	≥ 20	766736	595.16	2079.27	19563.78	456.3
	Average	766736	595.16	2097.27	19563.78	456.3
Hypertension	0-9	17632	37.16	51.85	132.14	0.7
	10-19	42691	241.54	436.87	1186.45	10.3
	20-29	266550	74.09	199.29	1852.00	19.7
	30-39	563863	96.74	369.69	6427.20	54.6
	40-49	1000099	183.71	627.80	5504.85	183.7
	50-59	1720562	264.21	1502.78	22771.07	454.6
	60-69	1763206	486.97	3950.75	60588.00	858.6
	70-79	1025353	115.82	428.34	9144.00	118.8
	80-89	343210	176.83	358.22	2391.58	60.7
	90-99	21317	80.95	63.68	140.70	1.7
	100+	5215	37.80	0.00	37.80	0.2
	≥ 20	6709375	261.22	2192.97	60588.00	1752.6
	Average	6769698	260.15	2183.48	60588.00	1763.6
Ischemic HD	10-19	4014	0.00	0.00	0.00	0.0
	30-39	21589	102.33	99.31	239.82	2.2
	40-49	138574	4691.54	8048.54	23840.63	650.1
	50-59	416557	1346.61	2772.72	14697.77	560.9
	60-69	381771	1556.08	4631.68	23413.50	594.1
	70-79	187042	769.57	2370.64	12571.90	143.9
	80-89	74932	1174.44	3013.67	11320.83	88.0
	≥ 20	1220465	1670.91	4400.88	23840.63	2039.3
	Average	1224479	1665.43	4394.70	23840.63	2039.3
Nonspecific HD	0-9	4451	0.00	0.00	0.00	0.0
	10-19	18671	402.77	763.10	2009.00	7.5
	20-29	41827	974.21	1958.24	4966.51	40.7

30–39	20574	1063.75	1614.51	3543.00	21.9
40–49	204956	2032.02	4906.42	23883.04	416.5
50–59	524168	1375.39	5077.84	38375.75	720.9
60–69	595206	1274.62	4634.08	43326.75	758.7
70–79	426144	2224.78	7825.51	49743.00	948.1
80–89	202381	589.05	2070.29	15360.86	119.2
90–99	37315	276.94	450.81	1194.00	10.3
100+	5215	73.30	0.00	73.30	0.3
> 20	2057786	1475.72	5353.93	49743.00	3036.7
Average	2080908	1462.93	5325.98	49743.00	3044.2

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APPENDIX

Table A.1 Coefficients of Non-Health Variables in Participation Equation

	Coefficient	t-Ratio
Married[a]	0.8989	5.89
No. in household	-0.1290	2.58
No. children < 5[a]	0.4072	2.56
No. children 5-18[a]	0.1060	1.34
No. children > 18[a]	0.3216	2.23
Age dummies:		
18-24	-1.2822	5.92
35-44	1.1440	4.28
45-54	1.5330	3.75
55-65	2.2198	3.55
Highest educ. level:		
Elementary school	-0.2006	0.84
High school	0.1312	0.65
College	0.0386	1.38
Nonwhite	-0.5886	3.39
Regional dummies[a]:		
Northcentral	0.3662	2.17
South	-0.1020	0.64
West	-0.0808	0.45
Lives in Urban Area[a]	0.1852	1.46
(Age-16)^2	-0.00160	4.54
Veteran	-0.1077	0.81
Aware of disability benefits	-1.0358	8.68
Debt[a]	0.00004	2.56

[a]Measured as of interview date

Table A.2 Coefficients of Remaining Health Variables in Participation Equation

Disease	Coefficient	t-Ratio
Arthritis or rheumatism	-0.2791	1.65
Other trouble with back or spine	-0.4597	2.79
Deformity of foot, leg, arm, hand	-0.3741	1.89
Nervous or emotional problems	-0.8574	4.10
Deformity of back or spine	-0.7925	3.53
Deafness	-0.2624	1.08
Stomach ulcer	-0.2714	1.11
Diabetes	-0.1334	0.49
Hernia or rupture	0.005837	0.02
Difficulty reading (with glasses)	-0.2017	0.65
Kidney stones or kidney trouble	-0.1528	0.48
Other chronic stomach trouble	-0.2896	0.85
Tumor, cyst or growth	0.1030	0.27
Hissing arms, hands or fingers	-0.5395	1.42
Gallbladder or liver trouble	-1.1440	2.40
Paralysis	-1.9011	3.49
Alcohol or drug problems	-1.4264	2.46
Cancer	-0.82301	1.56
Epileptic seizures	-1.5235	2.18
Mental illness	-1.0498	1.60
Blindness	0.1043	0.16
Thyroid trouble or goiter	-0.2380	0.39
Missing legs or feet	-0.5794	0.84
Tuberculosis	0.1099	0.09
Multiple sclerosis	-2.3758	1.78

Table A.3 Coefficients of Non-Health Variables in Earnings Equation

	Coefficient	T-Ratio
Married[a]	0.267	2.439
No. in household	-0.071	1.736
No. children < 5[a]	0.050	0.634
No. children 5-18[a]	0.058	1.117
No. children > 18[a]	0.003	0.034
Age dummies:		
18-24	- 0.421	2.771
35-44	0.230	1.601
45-54	0.229	0.936
55-65	0.364	0.941
Highest educ. level:		
Elementary school	-0.096	0.644
High school	0.004	0.036
College	0.294	2.271
Nonwhite	-0.195	1.550
Regional dummies[a]:		
Northcentral	0.111	1.136
South	0.011	0.113
West	- 0.025	0.231
Lives in Urban Area[a]	0.117	1.527
$(\text{Age-16})^2$	-0.0002	0.806

[a]Measured as of interview date
Note: Dependent variable is ln(earnings).

Table A.4 Coefficients of Remaining Health Variables in Earnings Equation

Disease	Coefficient	t-Ratio
Arthritis or rheumatism	-0.051	0.415
Other trouble with back or spine	-0.033	0.296
Deformity of foot, leg, arm, hand	0.043	0.301
Nervous or emotional problems	-0.208	1.075
Deformity of back or spine	-0.297	1.597
Deafness	-0.226	1.257
Stomach ulcer	-0.031	0.174
Diabetes	-0.300	1.690
Hernia or rupture	0.059	0.290
Difficulty reading (with glasses)	-0.136	0.520
Kidney stones or kidney trouble	-0.341	1.409
Other chronic stomach trouble	0.242	0.954
Tumor, cyst or growth	-0.327	1.368
Hissing arms, hands or fingers	0.354	1.340
Gallbladder or liver trouble	0.290	0.604
Paralysis	-2.931	4.518
Alcohol or drug problems	0.355	0.594
Cancer	-1.003	2.215
Epileptic seizures	-1.865	2.795
Mental illness	-0.010	0.015
Blindness	-0.001	0.002
Thyroid trouble or goiter	-0.044	0.100
Missing legs or feet	0.356	0.580
Tuberculosis	0.184	0.246
Multiple sclerosis	0.653	0.506

ESTIMATING THE VALUE OF AVOIDING MORBIDITY AND MORTALITY FROM FOODBORNE ILLNESSES

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May 1989

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I INTRODUCTION

All foods produced for human consumption in the United States are regulated for composition, quality, safety, and labeling under the Food, Drug, and Cosmetic (FD&C) Act of 1938 and its subsequent amendments. One of the chief goals of the FD&C Act is to reduce the presence of contaminants or adulterants in domestic and imported foods. Consuming foods that contain illegal contaminants or adulterants increases the risk of foodborne illness and decreases consumer welfare. The Food and Drug Administration (FDA) is empowered to ensure compliance of the FD&C Act for all domestic and imported food products. FDA's compliance monitoring program and enforcement activities reduce the probability of violative products reaching consumers and causing welfare losses.

FDA's objective is to maximize social welfare subject to a given compliance monitoring budget. The optimal solution is to allocate program resources across different inspection and enforcement activities to the point where the incremental value per unit expenditures for all activities are equal. To develop such an efficient compliance monitoring program, FDA must consider the costs and benefits of different alternatives. The costs of such programs consist primarily of the value of resources used to inspect and test products, and ensure compliance. The benefits of compliance monitoring activities depend on:

- the impact of compliance activities on the probability that violative products will reach the consumer,
- the probability that each violation will lead to various adverse health effects (e.g. salmonellosis, botulism cancer, or chemical poisoning), and
- the value of the welfare losses associated with each adverse effect.

Figure 1 shows how estimates of the three factors noted above can be combined to estimate the benefits of different compliance monitoring options. Calculating these values is not a straightforward task, however, and requires careful analysis. For example, the impact of compliance activities on the probability of a violative product reaching the consumer depends both on the initial probability of the product violating the FD&C Act as well as on how effectively the compliance monitoring and enforcement activity reduce this probability. The probability of a product violating the Act may vary overtime and with country of origin.

The probability that any violation of the Act adversely affects a consumer will depend on the type and degree of the violation. Food contaminated with salmonella will be more likely to have an adverse effect on a consumer if the level of contamination is high, if the typical portion size is large, and if the product is eaten without further cooking. Furthermore, the relationship between dose and the probability of an adverse response may vary for different violations of the Act. For example, the probability of an adverse health effect associated with frequently ingested levels of salmonella or botulinum toxin may be high, while the probability of cancer as a result of ingesting carcinogenic pesticides above the permissible levels may be much lower.

Finally, the value to consumers of avoiding the welfare losses associated with adverse health effects depends on how soon the effect occurs after they consume the violative product and the magnitude of the expected welfare losses.

This paper develops a methodology for estimating the value of the welfare gains associated with avoiding statistical cases of morbidity and mortality from foodborne illnesses. We demonstrate the methodology for botulism, salmonellosis, chronic hepatitis, and bladder cancer. The methods and results from this research can be combined with information on the costs of enforcement, dose-response relationships, and changing probabilities of violations to guide FDA in developing an efficient compliance monitoring program.

II BACKGROUND

Consumers derive value from a food inspection and monitoring program through lower risks of adverse health effects. When a compliance monitoring program detects and removes a violative product from distribution, it reduces the risk of consumers suffering adverse health effects and corresponding welfare losses. The value of reducing the risks of adverse health effects could be easily measured by market clearing prices if there were markets for health risks. With the exception of wage premiums for occupations with higher than average risks of on-the-job death or injury, health risks are not a market commodity. Thus, analysts must develop other methods to estimate the value of reducing food-related health risks.

One of the earliest approaches used to estimate directly the costs associated with different illnesses is the cost-of-illness (COI) methodology. In its simplest form, the COI methodology calculates the dollar cost of illness or disease as the sum of the present values of the medical resources used to diagnose and treat the disease and the individual productivity losses it causes. The COI methodology is a practical simplification of the more comprehensive human capital approach to valuing illness. Cooper and Rice (1976) and Rice, Hodgson, and Kopstein (1985)

have used the COI method to estimate the costs of many different diseases. Hartunian et al. (1981) employed the COI model to value the costs of coronary heart disease, stroke, cancer, and motor vehicle injuries.

The COI method is well-suited for estimating many of the tangible costs of illnesses, but it does not address any of the intangible or disutility costs. Nor does it distinguish between avoidance of identified cases of illness and reduction in the risk of adverse health effects. Utility is a conceptual device used primarily by economists to measure the amount of well-being and pleasure an individual experiences. Utility declines with deteriorating health status, as well as with increased risk of illness. Since the benefits of a government regulation are best described in terms of statistical cases of illness avoided, we fist estimate the value of utility gains from decreased risks of statistical illness.

While utility is a useful construct in theory, it is unobservable in practice. Thus, we need to derive proxy measures for utility changes such as monetary values. The concept of willingness to pay (WTP) has gained acceptance in the economics profession as a dollar equivalent to utility changes. The WTP approach is based on macroeconomic utility theory and has been used extensively to estimate the value of utility improvements and the cost of utility reductions. For example, the WTP approach imputes the cost of adverse health consequences by measuring how much individuals are willing to pay for small reductions in the risk of those effects. By measuring the value individuals place on small changes in the probability of mortality and morbidity, economists and health professionals have extended the analysis to measure the disutility cost of a statistical mortality and morbidity case.

Although dollars may bean imperfect measure of a consumer's valuation of avoided utility losses, within a certain range of preferences, people are familiar with the process of expressing values for goods and services through prices. Furthermore, dollar values provide a benchmark by which a wide variety of foodborne illnesses can be measured and compared.

We present a methodology for estimating the dollar value of avoiding morbidity and mortality from foodborne illnesses using both the willingness-to-pay approach and the cost of illness approach. We demonstrate our methodology and derive valuation estimates for avoiding statistical cases of botulism, salmonellosis, chronic hepatitis, and Madder cancer.

III METHODS AND RESULTS

The empirical model presented here was developed using publicly available data. We used the model as part of a larger study to estimate the value of avoiding both health and

nonhealth adverse effects from consuming foods that violate the FD&C Act (Mauskopf et al. 1988). In this paper, we only describe and implement the method for estimating the value of avoiding adverse health effects.

The method we use to compute the dollar value for avoiding foodborne illnesses associated with violations of the FD&C Act consists of the following seven steps and is illustrated in Figure 2:

- Identify the foodborne illnesses of concern.
- Describe the adverse health effects of each foodborne illness on an individual consumer.
- Translate these health effects into time spent in specific health states.
- Estimate the gains in quality-adjusted life-years (QALYs) associated with avoiding a case of each foodborne illness.
- Estimate the value of a QALY.
- Compute the willingness-to-pay estimate for avoiding each foodborne illness by combining the estimates of the QALYs avoided and the dollar value of a QALY.
- Use the estimated adverse health effects to compute the cost-of-illness estimates for each foodborne illness.

We discuss each step of the analysis in the following sections.

Identify Foodborne Illnesses

In the first step of the analysis, we use available human and nonhuman data to identify illnesses likely to be associated with violations of the FD&C Act (FASEB, 1988). In some cases, a cause-and-effect relationship between a violation and an illness is well-established, such as that between botulinum toxin and botulism. In other cases, this relationship maybe less understood, such as that between pesticide residues and risk of cancer.

To facilitate the later steps in the estimation procedure, we subdivide foodborne illnesses into three categories:

- acute illnesses, which occur with no latency period after exposure, have a well-defined duration, and end in either death or complete cure;
- chronic illnesses, which have no (or a short) latency period after exposure, a prolonged duration, and end in death; and

- cancers, which have a prolonged latency period, short or prolonged duration, and end in either death or complete cure.

Most foodborne illnesses can be assigned to one or more of these categories. Table I presents some examples of violations of the FD&C Act and their associated foodborne illnesses. Botulism is caused by botulinum toxin in a food product and is classified as an acute illness. Survivors of a severe case of botulism might also suffer from residual chronic illness, but this is not included in our analysis. Salmonellosis is caused by a bacterium and is a common disease in its less severe forms. Chronic hepatitis may persist throughout an individual's life after an attack of acute foodborne hepatitis. Certain pesticide residues and food coloring agents may be associated with an increased risk of bladder cancer.

Describe the Health Impact an Consumers

In general, foodborne illnesses can occur at various levels of severity, each of which affects the consumer to a different degree. To simplify the analysis, we chose three levels of severity for each illness: mild, moderate, and severe. We define the severity category for the acute and chronic illnesses based on well-defined clusters of symptoms, resource use, and/or mortality risk The severity levels are used for all illnesses except cancers, which we define as local, regional, and distant.

For each level of illness severity, we describe the impact on consumers in terms of patient symptoms, mortality rates, duration of treatment and recovery, frequently used medical treatment, and functional status during treatment and recovery. Functional status during the illness is defined as either in a hospital, in bed at home, or at home not in bed. Table II illustrates an impact profile for botulism salmonellosis, and chronic hepatitis. Table III illustrates the impact profile for bladder cancer. We obtained the data for these impact descriptions from the medical and clinical literature.

Determine Time Spent in Specific Health States

Adverse health effects from foodborne illnesses can cause both short- and long-term changes in health status. We classify the length and degree of health status changes by the time spent in specific health states. Health states can be defined broadly or narrowly depending on the conditions and purpose of the analysis. Several studies in the biomedical literature have developed health states or health status index scales to describe and categorize the adverse health consequences from illness and disease.

For this analysis, we use the set of health states defined by Rosser and Kind (1978). But analysts can use any set of health states general enough to be applied to all foodborne illnesses and for which relative utility weights have been estimated. In our comprehensive study for FDA (Mauskopf et al. 1988), we also used the Bush et al. (1981) health status index and the health status index developed for a study of vaccines by the Institute of Medicine (1985). Table IV presents the Rosser and Kind health state definitions. They express health status in terms of two dimensions: objective disability and distress.

After choosing a set of health states, we describe the adverse health effects from each foodborne illness in terms of time spent in the specific health states. The descriptions are presented for botulism, salmonellosis, and chronic hepatitis in Table V and for bladder cancer in Table VI using the Rosser and Kind health states. For example, we estimated that a mild case of botulism would result in severely limited ability to work for five days with mild distress. In contrast, we estimated a serious case of botulism would result in 90 days confined to bed in severe distress, 30 days confined to a chair in moderate distress, and 60 days unable to work in mild distress.

Estimate Losses in Quality-Adjusted Life-Years

To estimate the QALYs lost as a result of a foodborne illness, it is necessary to make a series of assumptions including age at exposure to the violative product, latency period after exposure for the illness to appear, remaining life expectancy at time of illness, and health status at onset of illness and for remaining lifetime. We assume the following baseline conditions:

- age at exposure is 30 years,
- a 20-year latency period for cancer, but no latency period for acute or chronic effects,
- remaining life expectancy at age 30 and at age 50 is 46 years and 26 years respectively,
- individuals are in perfect health and, in the absence of foodborne illness, would continue in perfect health for their remaining lifetime.

Lipscomb et al. (1983) have shown that this last assumption results in overestimates of the losses associated with illness of about 5 percent.

Using the assumptions noted above, the estimated time spent in specific health states for each foodborne illness, and the relative utility (well-being) weights shown in Table VII for the Rosser and Kind index, we computed the losses in QALYs associated with each illness.

Table VIII presents the estimated losses in QALYs for botulism, salmonellosis, chronic hepatitis, and bladder cancer.

For botulism, the estimated losses in QALYs are much larger for those who die from the disease (25.5 QALYs discounted at 3 percent or 46 QALYs undiscounted) than for those who have a severe case and survive (0.647 QALYs). For chronic hepatitis, the losses in QALYs are assumed to continue for the rest of the individual's lifetime. We estimate that approximately 50 percent of the people with bladder cancer die. In addition to suffering premature death, those individuals who die from bladder cancer suffer significantly greater losses from morbidity (0.31 undiscounted QALYs) than those who survive (0.07 undiscounted QALYs).

Estimate the Value of a Quality-Adjusted Life-Year

We use willingness-to-pay estimates for reductions in morbidity and mortality risks to assign a dollar value to a QALY. The process follows a series of steps. First, we explored the literature and chose a representative willingness-to-pay estimate for the value of a statistical life. We selected $5 million. This value was estimated by Viscusi and Moore (1988) in a recent study of wage premiums paid to workers in risky occupations with an average age of 40 years. Five million dollars serves as the willingness-to-pay estimate to avoid the index state (death) from a previous condition of perfect health. We assume that the remaining life expectancy for a 40-year-old worker is 36 years. Using a value estimated for a statistical life (death) is appropriate, because FDA monitors and enforces programs that reduce the risk of foodborne illness for the general population, thus preventing statistical, not identified, cases.

Equation 1 illustrates the formula we use to compute the undiscounted value of a QALY from the estimated value of a statistical life.

$$\$\text{QALY (0\% discount)} = \frac{\text{value of a statistical life}}{\text{remaining life expectancy}} \tag{1}$$

Alternatively, for a discount rate of 3 percent, we first convert remaining life expectancy to total discounted life-years (TDLYs) through the following calculation:

$$\text{TDLYs remaining} = \sum_{i=1}^{36} \frac{1}{(1+0.03)^{i-1}} = 22.5, \tag{2}$$

and then compute the value of a QALY as:

$$\$\text{QALY (3\% discount)} = \frac{\text{value of a statistical life}}{\text{total discounted life-years}} \tag{3}$$

Using $5,000,000 as the value of a statistical life (Viscusi and Moore, 1988), the estimated value of a QALY is $138,000 at a 0 percent discount rate, and $222,222 at a 3 percent discount rate.

In computing the value of a QALY as described above, we used death as the index state. Alternatively, the value of a QALY can be computed from estimates of the willingness-to-pay to avoid other adverse health states, provided that the lost QALYs associated with these adverse health effects are also estimated. For example, Rowe and Chestnut (1984) estimated the willingness to pay to avoid a bad asthma day at $23.00. Using the Rosser and Kind scale, the loss in QALYs associated with a day with asthma is estimated as 0.00008. Thus, using a day of asthma as the index state will result in an estimate for a QALY of $287,500. This exercise can be performed for a variety of different index states to generate a range of estimates for the value of a QALY.

Estimate the Value of Avoiding Morbidity and Mortality

In the final step of the willingness-to-pay analysis, we compute the product of the QALYs gained and the dollar value of a QALY to generate willingness to-pay estimates for the avoided morbidity and mortality associated with foodborne illnesses. Estimated values for botulism, salmonellosis, chronic hepatitis, and bladder cancer are presented in Table IX. The estimated dollar value for avoiding foodborne illnesses associated with a high risk of death, such as severe botulism or bladder cancer, is much higher than for avoiding nonfatal illnesses such as mild or moderate cases of salmonellosis. Nevertheless, the estimated morbidity losses are not insignificant.

Caution must be exercised when interpreting the implications of these estimates. Many serious foodborne illnesses are rare, such as those presented as examples here. Since the willingness-to-pay values are for statistical cases of each illness, the aggregate value of avoiding all cases may be relatively small in comparison to a less severe illness with a much higher prevalence. As an example, foodborne illnesses such as salmonellosis are usually not life threatening, yet they are very common, especially in their milder forms. Consequently, the total dollar losses associated with morbidity from this disease may be very high—in the billions of dollars (Archer and Kvenberg 1985).

Estimate Morbidity and Mortality Losses Using the Cost-of-Illness Approach

An alternative approach to estimating the value of avoiding foodborne illnesses is to estimate the direct and indirect costs avoided in terms of medical care and productivity losses.

The cost-of-illness method advocates an accounting cost framework to estimate the observable costs (medical care) and an opportunity cost framework to estimate the implicit costs (productivity losses). Cost-of-illness estimates for botulism, salmonellosis, and bladder cancer are presented in Table X.

Cost-of-illness methods have been applied in numerous studies for many different illnesses and diseases. Despite its popularity, the cost-of-illness method tends to underestimate the true value of the avoided illness because it does not address the value of avoiding certain cost categories (e.g., pain and suffering). On the other hand, the cost-of-illness method may overestimate the value of the avoided medical costs to the individual because these costs are often shared via health insurance.

IV CONCLUSION

We described two methods that can be used to estimate the value of avoiding the morbidity and mortality associated with foodborne illnesses: willingness-to-pay and cost-of-illness. We demonstrated the use of these methods and estimated the value of avoiding statistical cases of four foodborne illnesses: botulism, salmonellosis, chronic hepatitis, and bladder cancer. At least three conclusions can be drawn as a result of this analysis. First, the fatality rate is the key factor when determining the relative value of avoiding different levels of severity for acute illnesses and cancers. Second the value of morbidity losses, both for those ultimately dying from the illness and for those surviving, are significant. Finally, the estimated value of avoiding chronic diseases is critically dependent on the degree of functional impairment associated with the illness.

Although the cost-of-illness method is a convenient approach for estimating the tangible costs of illness and disease, it is flawed because it does not consider disutility costs. Willingness-to-pay methods are conceptually appealing because they are based on microeconomic utility theory. Willingness-to-pay estimates include the disutility costs associated with illness and disease such as physical and emotional pain and suffering.

Despite its theoretical strengths, the willingness-to-pay approach can be difficult to implement due to data requirements. In addition, the estimates are highly sensitive to simplifying assumptions and baseline parameter values (e.g., age at exposure, remaining life expectancy, discount rate, health status index scale). Although these issues cannot be ignored, our methodology is able to use secondary data to generate defensible estimates for the value of avoiding a wide variety of morbidity states. More importantly, decisionmakers can use this

methodology to include the value of reducing morbidity risks as well as the value of reducing mortality risks in their benefits estimates. This is especially useful for FDA and other federal agencies that regulate health risks.

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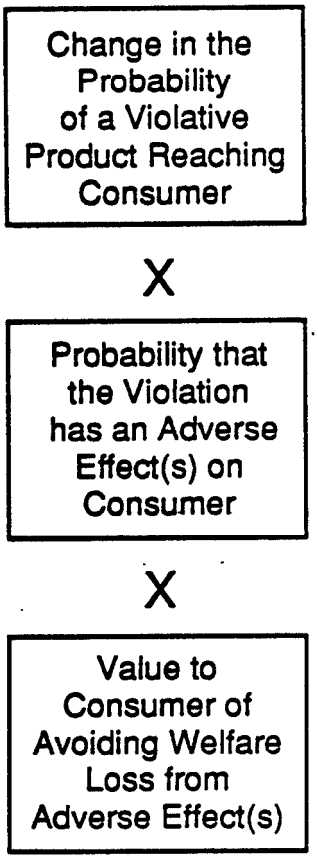

Figure 1. Benefits of Compliance Monitoring

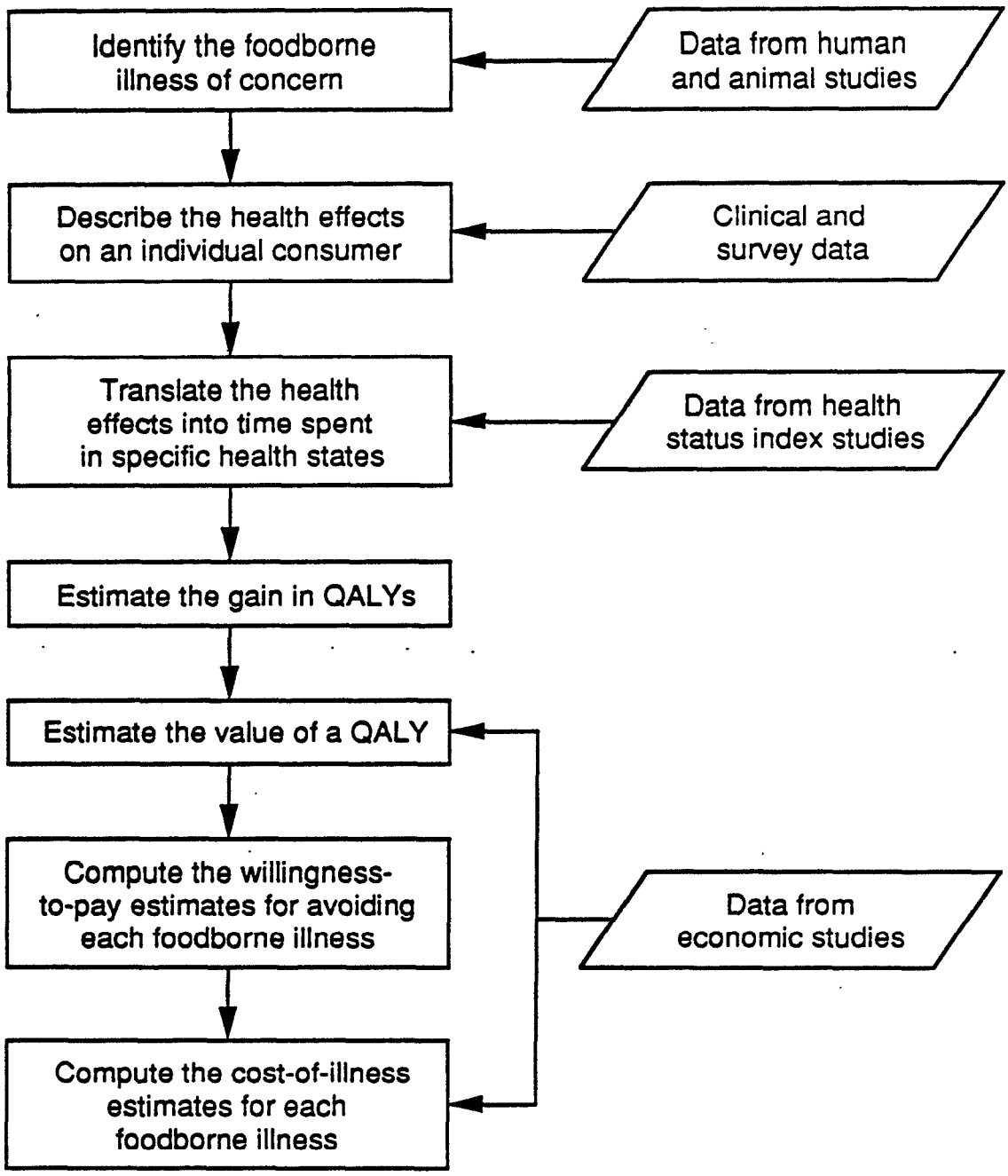

Figure 2. Flow Diagram of Estimation Model

TABLE I. SAMPLE OF FOODBORNE ILLNESSES CAUSED BY VIOLATIONS OF THE FD&C ACT

Violation	Acute Effects	Chronic Effects	Cancers
FD & C Red#10	Contact dermatitis		Bladder
Cat filth/damage	Toxoplasmosis	Congenital toxoplasmosis	
C. Botulinum	Botulism		
Human filth	Shigellosis, hepatitis, listeriosis, colitis	Chronic hepatitis, cirrhosis	Liver
Salmonella	Salmonellosis		
Inadequate. pasteurization, LACF	Salmonellosis, botulism		
Sulfite	Allergic response		

TABLE II. HEALTH EFFECTS OF BOTULISM, SALMONELLOSIS, AND CHRONIC HEPATITIS

Illness	Symptoms	Duration	Treatment	Functional Status	Fatality Rate
Botulism					
Mild	Malaise, weakness, fatigue	5 days	Antitoxin	5 house days	0%
Moderate	Nausea/vomiting, diarrhea, abdominal pain, fever, malaise, weakness, headache, dizziness	21 days	Antitoxin	7 hospital days 7 bed days 7 house days	0%
Severe	Same as moderate plus respiratory paralysis, muscular paralysis, pulmonary infection	180 days	Antitoxin, respiratory support	90 hospital days 30 bed days 60 house days	22.5%
Salmonellosis					
Mild	Nausea/vomiting, diarrhea abdominal pain, anorexia weakness	3 days	Oral fluids, antispas-medics	2 bed days 1 house day	0%
Moderate	Same as mild plus fever, headache, dehydration/ prostration	7 days	Oral fluids, antispas-medics	4 bed days 3 house days	0%
Severe	Same as moderate plus enteric bacteremia	11-20 days	I.V. fluids, antispas-medics, antibiotics	5-14 hospital days 3 bed days 3 house days	13%
Chronic Hepatitis					
	Malaise	1 year to lifetime	None	Very minor restrictions	o%

Sources: FASEB (1988), Mann et. al., (1983), Todd (1985a), Todd (1985b), CDC (1980).

TABLE III. HEALTH EFFECTS OF BLADDER CANCER

Estimated Duration of Treatment, Cured Patients =	< 2 years
Estimated Duration of Treatment, Uncured Patients =	1.97 years
Estimated Fatality Rate =	51%

Associated Signs and Symptoms

Bloody urine
Pain on urinating
Abdominal pain
Further symptoms from metastasis

Frequently Used Medical Treatments and Associated Side Effects

Surgery
- *Pain*
- *Discomfort*

Radiation Therapy
- *Diarrhea*
- *Mucositis which can preclude substantial oral intake and lead to malnutrition*

Chemotherapy
- *Nausea*
- *Vomiting*
- *Hair loss*
- *Inflammation of mucous membranes*
- *Suppression of white cell development*
- *Cerebellar dysfunction at high doses*
- *Anorexia*
- *Rashes*
- *Inflammation of hair follicles*
- *Hyperpigmentation*
- *Fever/chills*
- *Renal failure*
- *Anemia*

Functional Status During Treatment and Recovery

Cured Patients	**First Year**	**Second Year**
Hospital Days	10	7
Days of Hospital Recovery	8	6
Chemotherapy Days		0
Days of Chemotherapy Recovery	0	0
Radiation Therapy Days	0	0
Days of Radiation Therapy Recovery	1	
Mild Distress Days	345	170

Uncured Patients	**First Year**	**Second Year**
Hospital Days	18	35
Days of Hospital Recovery	14	28
Chemotherapy Days	3	24
Days of Chemotherapy Recovery	3	24
Radiation Therapy Days	7	14
Days of Radiation Therapy Recovery	3	7
Nursing Home Days	0	7
Partial Disability Days		
Total Disability Days	0	41
Mild Distress Days	317	144

TABLE IV. ROSSER AND KIND HEALTH STATES

Objective Disability	Distress
1. None	1. None
2. Slight social disability	2. Mild
3. Severe social disability, slight impairment at work	3. Moderate
4. Work severely limited	4. Severe
5. Unable to work	
6. Confined to chair	
7. Confined to bed	
8. Unconscious	

Source: Rosser and Kind (1978)

TABLE V. DISABILITY, DISTRESS, AND TIME IN SPECIFIC HEALTH STATES FOR BOTULISM, SALMONELLOSIS, AND CHRONIC HEPATITIS

Illness	Disability Index	Distress Index	Duration
Botulism			
Mild	4	2	5 days
Moderate	7	3	7 days
	6	3	7 days
	4	2	7 days
Severe	7	4	90 days
	6	3	30 days
	4	2	60 days
Salmonellosis			
Mild	6	3	1 days
	4	2	1 days
Moderate	6	3	4 days
	4	2	3 days
Severe	7	3	10 days
	6	3	3 days
	4	2	3 days
Chronic Hepatitis	2	2	365 days/year

TABLE VI. DISABILITY, DISTRESS, AND TIME IN SPECIFIC HEALTH STATES FOR BLADDER CANCER

Duration			Functional Status During Treatment and Recovery*	
First Year	Second Year		Disability Index	Distress Index
		Cured Patients		
10	7	Hospital Days	7	3
8	6	Days of Hospital Recovery	6	3
0	0	Chemotherapy Days	5	3
0	0	Days of Chemotherapy Recovery	4	2
1	0	Radiation Days	5	3
1	0	Days of Radiation Recovery	4	2
345	170	Mild Distress Days	1	2
		Uncured Patients		
18	35	Hospital Days	7	3
14	28	Days of Hospital Recovery	6	3
3	24	Chemotherapy Days	6	3
3	24	Days of Chemotherapy Recovery	5	3
7	14	Radiation Days	6	3
3	7	Days of Radiation Recovery	5	3
0	7	Nursing Home Days	7	3
0	41	Partial Disability Days	4	2
0	41	Total Disability Days	6	3
317	144	Mild Distress Days	1	2

* Weighted average for cases diagnosed in local, regional, and distant stages.

TABLE VII. RELATIVE UTILITY WEIGHTS FOR THE ROSSER AND KIND HEALTH STATUS INDEX

Disability Index	Distress Index			
	1	*2*	*3*	*4*
1	1.0	0.995	0.990	0.967
2	0.990	0.986	0.973	0.932
3	0.980	0.972	0.956	0.912
4	0.964	0.956	0.942	0.870
5	0.946	0.935	0.900	0.700
6	0.875	0.845	0.680	0.000
7	0.677	0.564	0.000	-1.486
8	-1.028	—	—	—

Source: Rosser and Kind (1978)

TABLE VIII. LOSSES ON QUALITY-ADJUSTED LIFE-YEARS FROM BOTULISM, SALMONELLOSIS, CHRONIC HEPATITIS, AND BLADDER CANCER

Illness	Fatality	Loss for survivors QALYs* (QALDs)**	Weighted Average Loss QALYs* (QALDs)**
Botulism			
Mild	0%	0.00055 (0.2)	0.00055 (0.2)
Moderate	0%	0.0263 (9.6)	0.0263 (9.6)
Severe	22.5%	0.647 (236)	6.24 (2,279)
Salmonellosis			
Mild	0%	0.001 (0.4)	0.001 (0.4)
Moderate	0%	0.004 (1.4)	0.004 (1.4)
Severe	13%	0.03 (11.1)	3.35 (1,221)
Chronic Hepatitis	0%	0.36 (130.4)	0.36 (130.4)
Bladder Cancer			
Undiscounted	51%	0.068 (24.7)	12.9 (4,700)
Discounted 3% to Diagnosis	51%	0.067 (24.4)	9.57 (3,494)
Discounted 3% to Exposure	51%	0.037 (13.5)	5.30 (1,934)

* QALY = quality-adjusted life-year

** QALD = quality-adjusted life-day

TABLE IX. WILLINGNESS-TO-PAY ESTIMATES FOR AVOIDING BOTULISM, SALMONELLOSIS, CHRONIC HEPATITIS, AND BLADDER CANCER

Illness	Fatality Rate	Survivors	Weighted Average
Botulism			
Mild	0%	$130	$130
Moderate	0%	$5,800	$5,800
Severe	22.5%	$143,750	$1,388,000
Salmonellosis			
Mild	0%	$222	$222
Moderate	0%	$890	$890
Severe	13%	$6,700	$740,000
Chronic Hepatitis	0%	$79,400	$79,400
Bladder Cancer			
Undiscounted	51%	$8,220	$1,178,000
Discounted 3% to Diagnosis	51%	$9,384	$1,780,000
Discounted 3% to Exposure	51%	$14,900	$2,127,000

TABLE X. COST-OF-ILLNESS ESTIMATES FOR AVOIDING BOTULISM, SALMONELLOSIS, AND BLADDER CANCER

Illness	Fatality Rate	Survivors	Weighted Average
Botulism			
Mild	0%	$470	$470
Moderate	0%	$4,710	$4,710
Severe	22.5%	$68,500	$195,000
Salmonellosis			
Mild	0%	$197	$197
Moderate	0%	$622	$622
Severe	13%	$65,556	$86,895
Bladder Cancer*	51%	$13,876	$215,000

* Lost earnings discounted at 3% to diagnosis.

UTILITY IMPAIRMENT YEARS:
A LOW-COST APPROACH TO MORBIDITY VALUATION

by

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May 1989

This research was supported by Federal Highway Administration contract DTFH-61-85-C-00107. The opinions expressed are strictly the authors'.

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Introduction

This article extends the Arthur (1981) social consumption equivalent (SCE) value of life model to one that also accounts for health status and serious injury. Death is only one possible outcome of risky activities, and by the available evidence, not always the least desirable. Fates worse than death are now recognized as important determinants of private decisions to avoid risk and of the social value of public programs designed to reduce or eliminate hazards to life and limb. Kind, Rosser, and Williams (1982) examined the impacts of distress and disability on the joy of living and found that permanent confinement to bed was considered as bad as death, and permanent coma even worse. In a British study of injury severity by Green and Brown (1978), university students ranked death third behind brain damage and paralysis from the neck down. Jones-Lee, Hammerton, and Philips (1985) found that in a probability sample of 1000 British residents, the median individual considered lifetime confinement to a wheelchair as bad as death, and being permanently bedridden was considered as bad or worse than death by 63 percent of the respondents. Howard (1984) has examined the theoretical implications of extreme disability for individual decisions regarding risk.

The impact of serious injury on individual and social welfare can be substantial, as implied by the findings cited above. Implicit in these data is the effect of injuries on the utility from additional years of life. A person's health status is likely to have a direct effect on welfare—particularly when pain and suffering are involved-as well as indirect effects such as diminished utility from consuming other goods.

In addition to their effects on the utility associated with additional years of life, permanent and temporary disabilities have important implications for the age profile of consumption, production, and mortality. Changes in the incidence of serious illness and injury also may have quite different implications than changes in the death rate from the same cause. The impact of a change in the incidence of serious injuries on labor market productivity and consumption may include offsetting effects, for example, depending on whether the change is associated with an increase or decrease in death rates. Reductions in the injury rate that are not offset by an increase in death rates should increase average labor productivity. The magnitude of these effects will depend on the age of the individual, time to recovery, and the extent to which it was already possible to switch to less physically demanding activities following a serious injury. Consumption of costly medical resources will decline with a reduction in the incidence of serious injury, perhaps more than offsetting any increase in other types of consumption.

The mortality implications of adding the seriously injured to the model can be viewed in terms of resuscitated lives—saving those who would have died as the result of a serious illness or injury through the application of advanced medical technology or improved health and safety measures—and should be contrasted with the elimination of a cause of death. The life-table implications of lifesaving of this type have been worked out in detail by Vaupel and Yashin (1985). Those who have been saved from death but not from serious injury subsequently face a different regime of mortality risks than those who have never been seriously injured. For example, the quadriplegic must forgo risk-producing activities, such as driving, but faces increased risks to life in other respects, for example, from infections.

The social consumption equivalent (SCE) framework allows one to trace the implication of changes in mortality across different ages on the various components of the model. The following section briefly summarizes the main points of the SCE model as it has been developed for death. Many of the more technical details are included in a footnote. The discussion includes a comparison of the SCE model with those based on willingness to pay and human capital. This is followed by a formal presentation of the revised model that includes health status as an additional argument of the utility function and a determinant of the age patterns of productivity, consumption, and mortality. Once health statuses are refined beyond the simple two-way classification alive-dead, it is necessary to confront the problem of measuring the utilities of alternative health states. The paper then reviews the utility measures available and examines their consistency and capability through illustrative valuations of selected illnesses and injuries.

The Social Consumption Equivalent Value of Life

The SCE method uses an age-specific, overlapping generation, economic model to assess the cost of loss of life or the value of lives saved as the result of a change in the pattern of mortality by age. The SCE method is: (1) based on economic welfare theory, (2) gives values in dollar terms that are a function of the age of the victim, (3) gives values that can be expressed in terms of human capital and willingness to pay, and (4) is fully actuarial. Under SCE, loss of life can be evaluated in three different ways: (1) by changes in age-specific life-table survival risks (caused, say, by improved highway design), (2) by “statistical” lives lost at a given age a, and (3)by cause (cancer, airline accidents) where loss.of life occurs with a known age incidence. SCE emphasizes that valuation must account for the additional consumption of those whose lives are saved or lengthened. For example, when a 70 year-old’s life is “saved,” society gains that person’s enjoyment or utility of additional years that are otherwise lost. But the extra consumption that supports utility in these additional years must be paid for--possibly by additional social security payments, by transfers from younger relatives, or by additional saving earlier in life.

The SCE method can be viewed in terms of two key relationships. The first of these is the social welfare function given by:

$$W = \int_0^{\omega} U[c(x),x]p(x)dx \qquad (1)$$

where U[c,x] is the utility of being alive at age x, given consumption rate c; p(x) is the probability of surviving from birth to age x; and w is the maximum age of surivorship. The second equation is given by the societal budget constraint:

$$\int_0^{\omega} e^{-gx}p(x)c(x)dx = (f(k)-gk)\int_0^{\omega} e^{-gx}p(x)\lambda(x)dx \qquad (2)$$

where g is the constant rate of population growth; $f(k)=F(K,L)/L$ is output per worker at capital-labor ratio K/L for an economy with constant returns to scale production function F; and $\lambda(x)$ is the age schedule of labor participation. [1]

By considering the total differentials of equations (1) and (2) with respect to an arbitrary pattern of changes in survival probabilities, Arthur was able to show that the change in expected lifetime welfare is given by:

$$\delta W = \int_0^\omega U[c(x),x]\delta p(x)dx$$

$$+ \partial U/\partial c(0)\ \{w \int_0^\omega e^{-gx}\lambda(x)\delta p(x)dx - \int_0^\omega e^{-gx}c(x)\delta p(x)dx + \beta\delta g[\delta p]\ \} \quad (3)$$

where w is the wage rate, and β is the life-cycle value of a marginal increase in the population growth rate (Arthur and McNicoll, 1978). This can be reexpressed more conveniently as:

$$\delta W = U_{\delta p} + \partial U/\partial c(0)\ \{\ wL_{\delta p} - c_{\delta p} + v_{\delta p}\beta/A_m\ \} \quad (4)$$

Life-Cycle Welfare Increase	Utility of Extra Life-Years	Value of Extra Labor-Years	Social Cost of Consumption Upkeep	Value of Additional Children

where L_δ and c_δ are the expectations of extra person-years of production and consumpton resulting from the particular variation δp, $v_{\delta p}$ is additional children per person due to the variation in mortality, and A_m the average age of reproduction in the stable population.

Equation (4) was used by Arthur (1981) to develop the social welfare equivalent of an increase in risk corresponding to the loss of one life selected at random at age a. In order to express the value of life in consumption units, Arthur assumed that utility function U does not vary with age and has constant elasticity of consumption:

$$U[c(x),x] = c^\varepsilon \quad (5)$$

where $\varepsilon=(dU/dc)(c/U(c))$ is the constant elasticity of consumption. The social consumption equivalent value of mortality variation δp is given by:

$$SCE[\delta p] = (1/\varepsilon - 1)c_{\delta p} + wL_{\delta p} + (\beta/A_m)v_{\delta p}. \quad (6)$$

Equation (6) makes explicit the fact that the enjoyment of additional years of life is directly offset by its consumption cost.

Equation (6) also provides a direct connection between the social consumption equivalent method and human capital and willingness-to-pay criteria for valuing variations in mortality risks. In Landefeld and Seskin's (1982) formulation, willingness to pay for life and safety (WTP) essentially equals the product of the present value of the individual's future monetary and nonmonetary goods consumption times A, the reciprocal of the goods consumption elasticity of lifetime utility. The first component is given in equation (6) by c_δ , and the second by $1/\varepsilon$. The human capital (HK) approach uses the present value of the change in expected lifetime earnings, With appears as the wL_δ term in equation (6).. Human capital net of consumption, thus, equals the negative part of the first term in (6) plus the second term. This suggests the following definition of SCE in terms of WTP and HK:

$$SCE[\delta p] = (1/\varepsilon)c_{\delta p} + wL_{\delta p} - c_{\delta p} + (\beta/A_m)v_{\delta p}. \quad (7)$$

Social Consumption Equivalent Value	Average Individual Willingness to Pay	Human Capital Net of Consumption	Value of Additional Children

Equation (7) shows that society's willingness to pay for mortality improvements may be greater or less than individual willingness to pay for the same change.

Adding Health Status to the Model

The SCE model can modified to include nonfatal risks by including a term for health status in the welfare function. We assume that each person has a utility function $U[c(x),h(x),x]$, where h(x) is defined as the "state of health" at age x. Health status is also assumed to have a direct impact on health costs, consumption, fertility, mortality, and labor productivity. Changes in fertility, mortality, and labor productivity will induce changes in the equilibrium stable population growth rate and the equilibrium capital-labor ratio. Suppose that some activity (e.g., less safe roads, changed airline regulations) alters the health state by $\delta h(x)$ over the age dimension. Suppose also that this change has associated with it direct health costs $\delta c_H[\delta h]$, and alterations in consumption $\delta c[\delta h]$, labor effectiveness $\delta\lambda[\delta h$ 1, mortality $\delta p[\delta h]$, and fertility $\delta m[\delta h]$. The latter are all directly observed changes for a specific category of injuries.

The social welfare function now takes the following form:

$$W = \int_0^\omega U[c(x),h(x),x] \cdot p(x)dx. \quad (8)$$

We can rewrite the societal budget constraint as:

$$\int_0^\omega e^{-gx}p(x)c(x)dx + \int_0^\omega e^{-gx}p(x)c_H(x)dx \equiv (f(k)-gk)\int_0^\omega e^{-gx}p(x)\lambda(x)dx \quad (9)$$

breaking out health costs and consumption expenses separately. The change in welfare caused by δh is given by:

$$\delta W = \partial U/\partial c(0) \int_0^{\omega} e^{-gx}\delta c[\delta h]p(x)dx + \int_0^{\omega} \partial U/\partial h \cdot \delta h(x)p(x)dx$$

Welfare Change of Adjustment in Consumption

Welfare Change Due to Changed Incidence of Injuries

$$+ \int_0^{\omega} U[c(x),h(x),x]\delta p[\delta h]dx. \qquad (10)$$

Welfare Change from Extra Years of Life

The change in h will also cause adjustments across the societal budget constraint:

$$0 = \int_0^{\omega} e^{-gx}c(x)\delta p[\delta h]dx + \int_0^{\omega} e^{-gx}\delta c[\delta h]p(x)dx$$

$$+ \int_0^{\omega} e^{-gx}c_H(x)\delta p[\delta h]dx + \int_0^{\omega} e^{-gx}\delta c_H[\delta h]p(x)dx$$

$$- (f(k)-gk)\left\{ \int_0^{\omega} e^{-gx}\lambda(x)\delta p[\delta h]dx + \int_0^{\omega} e^{-gx}p(x)\delta\lambda[\delta h]dx \right\}$$

$$- \delta k[\delta h](f'-g) \int_0^{\omega} e^{-gx}\lambda(x)p(x)dx - \beta\delta g[\delta h]. \qquad (11)$$

Equation (11) is identical to equation (N. 6) in footnote 1 except for the addition of the terms related to changes in medical costs ($\delta c_H[\delta h]$) and changes in labor productivity related to changes in health status ($\delta\lambda[\delta h]$). Also, the change in the population growth rate now includes the combined effect of changes in fertility and mortality.

Using equation (11) to substitute for the first term in equation (10) yields:

$$\delta W = \int_0^{\omega} U[c(x),h(x),x]\delta p[\delta h]dx + \int_0^{\omega} \partial U/\partial h \cdot \delta h(x) p(x)dx$$

$$+ \partial U/\partial c(0) \{ w \cdot [\int_0^{\omega} e^{-gx}\lambda(x)\delta p(x)dx - \int_0^{\omega} e^{-gx}\delta\lambda[\delta h]p(x)dx]$$

$$- \int_0^{\omega} e^{-gx}\delta c_H[\delta h]p(x)dx - \int_0^{\omega} e^{-gx}c_H(x)\delta p(x)dx$$

$$- \int_0^{\omega} e^{-gx}c(x)\delta p(x)dx + \beta\delta g[\delta h] \} \qquad (12)$$

This can be simplified to:

$$\delta W = U_{\delta p} + U_{\delta h}$$

Life-Cycle Welfare Increase = Utility of Extra Life Years + Utility of Improved Health Status

$$+ \partial U/\partial c(0) \{ wL_{\delta p} - wL_{\delta h}$$

Value of Extra Labor Years − Value of Increased Productivity

$$- c_{H,\delta h} - c_{H,\delta p}$$

Social Cost of Health Status Improvements − Social Cost of Health Maintenance Over Extra Years

$$- c_{\delta p} + (v_{\delta p}+v_{\delta m})\beta/A_m \} \qquad (13)$$

Social Cost of Consumption Upkeep + Value of Additional Children

Where L_δ, c_δ, and $c_{H\,\delta}$ are expected extra person-years of production, consumption, and health costs respectively, resulting from variation in mortality; $L_{\delta h}$, $c_{\delta h}$, and $c_{H,\delta}$ are the expected life-cycle increases in productivity, consumption, and health costs directly associated with improved health status; v_δ and $v_{\delta h}$ are additional children per person due to variation in mortality and health, respectively; and A_m is the average age of reproduction in the stable population.

A comparison of equation (13) with equation (3) indicates that improving health status has benefits and cost above and beyond those associated with improved longevity. There is a quality-of-life aspect to living longer, now

captured by the second term in equation (13), that was ignored in the original model. A healthier population will also be a more productive one, but at the additional social cost of maintaining good health. Finally, health status changes may affect fertility rates, which in turn affect social welfare either negatively or positively depending on the value of additional children to the society.

Empirical Estimation

This subsection describes methods for estimating each term in equation (13). The remainder of this section. provides illustrative applications.

Since health status is accounted for explicitly in the model, the utility per life year (the first term in the equation) should be uniform over time . Its value can be estimated from a study of individual willingness to pay for a statistical life by (a) selecting a discount rate, (b) computing the present value (in years) of the remaining expected lifespan for someone at the average age in the study population, and (c) dividing mean willingness to pay by mean expected life span. Miller (1986) identifies 25 studies of individual willingness to pay for a statistical life that are of reasonable quality. After adjusting such parameters as the value of time to make the values in the studies more comparable and adjusting for people's misperceptions of their fatality risks using the procedure in Blomquist (1982), the mean value of a statistical life across the studies was $1.95 million 1986 after-tax dollars with a standard deviation of $.5 million.

Almost all of the 25 studies involved populations with mean ages around 38. According to the Statistical Abstract (1988), the average remaining lifespan at age 38 is roughly 39 years. At a 6 percent discount rate, the value per life year at age 38 is about $120,000 or $350 per day. At a 2 percent discount rate, it is about $70,000 per year or $200 per day. By way of comparison, Moore and Viscusi (1988) estimates a statistical model of wage premiums for risk that indicates the average individual is willing to pay $90,000 for a life year and uses a 2 percent discount rate in safety decisionmaking.

The utility per year of improved health status—the second term in equation (13)--presents the greatest difficulty in valuation. Computation of differences in welfare associated with changes in health status requires knowing the utilities of alternative health states. Recent work on the measurement of health status (reviewed in the next section) provides the necessary data. This work produced scales indicating how utility loss varies with the nature and extent of functional loss.

If the utility values on a scale are normalized so that death has a value of zero and perfect health a value of one, the value associated with unit utility loss for one year will be the value of a life year. The utility in the second term is the product of the functional loss averted and the utility of this loss. To get a dollar value, this product is multiplied times the value of a 'functional life year.

The third through seventh terms in equation (13) together constitute the change in human capital net of consumption that results from the health status change. This is a societal externality. The value of extra labor years and increased productivity is measured by the gain in earnings attributable to averting the illness or injury. The social costs related to health status changes essentially we medical costs borne by third-party payers, charity, or government. The seventh term is the impact of the health status change on consumption, including consumption funded by transfer payments, insurance payouts, and earnings. Under the assumption that all bequests stay within the family, the change in the family's after-tax earnings that results from the illness or injury should equal the change in the family's earnings-related consumption--so they cancel out. Thus, the externalities resulting from reduced illness or injury equal taxes gained plus transfer payments (including medical care reimbursement) averted. The dollar value of the externalities generally can be computed from the extensive literature on costs of morbid conditions and data from the Health Interview Survey.

The explicit inclusion of transfer payments in the societal benefits is consistent with the generally accepted principle that transfer payment reductions are not benefits (see, for example, Klarman, 1965 or Hu and Sandifer, 1981). Rational individuals will pay less to avoid disability if transfer payments will cover some of the associated costs. Since transfer payments were subtracted from individual willingness to pay, their explicit addition yields zero net transfers in the societal benefit estimate.

The final term in equation (13) is the value of additional children born due to the health status improvement. Arthur (1981) estimates the value of this term as -$68,125 (in 1975 dollars), based strictly on the costs society incurs per child. This approach ignores the noneconomic benefits that parents derive from their children. Analyses of direct costs and opportunity costs of children (Espenshade and Calhoun, 1986) suggest these benefits are at least as large as the opportunity costs. In this article, therefore, the net value of this term is assumed to be negligible and is ignored in the computations.

Consistency of Empirical Estimates across Scales

The operations research and medical decision-making literature contains many scales that examine the multi-attribute utility loss associated with different health states. Some articles focus on individual diagnoses--for example, the utility loss associated with blindness or kidney failure. Others create functional ability scales and examine the utility associated with each state on the scale. Torrance (1982, 1986) evaluates the different methodological approaches used in this literature.

Tables 1 through 3 compare the utility loss that different scales suggest is associated with selected diagnoses. The studies by Green and Brown (1978), Card (1980), His et al. (1983), Miyamoto and Eraker (1985), Pliskin Shepard, and Weinstein (1980), Sackett and Torrance (1978), and Viscusi et al. (1989) directly estimate the utility loss associated with specific diagnoses. The other loss estimates in this table were computed by developing descriptions of the functional impairments associated with the diagnoses, then

computing the utility losses that each scale suggests are associated with these impairments. Impairments generally were evaluated on only a subset of the utility scales because the other scales did not include appropriate impairment categories.

This section first describes and evaluates the studies that provide utility loss estimates for at least two diagnostic conditions. Next, for each diagnosis, it compares the utility loss estimates across studies and substitutes the modal utility loss estimate into equation (13) to estimate an SCE value. This analysis is the first systematic attempt to validate the utility scales against one another or against utilities estimated from studies of specific illnesses and injuries. To provide a fairer test of the scales, we generally estimated the functional impairments on all scales first, then went back and computed the associated utility losses.

Available Scales Showing Utilities

Torrance (1982) conducted a survey of 112 parents of school-age children in Canada. The survey yielded utility loss estimates for scales that evaluated four dimensions of functioning: impaired physical function, role function (ability to work, play, etc.), social-emotional function, and health function. Pain is incorporated, somewhat cursorily, in the last category. Further analysis of the original ratings and supplemental interviews yielded a multiplicative equation for combining the utility losses across dimensions of impairment (Drummond et al., 1987). The utility losses have an uncertainty range (two standard deviations) of ± 12 percent. The four impairment scales are easy to use and applied to the widest range of diagnoses of any scale we tested. The equation for combining ratings is simple and conceptually appealing; it admits the possibility of fates worse than death and recognizes that the utility loss associated with an impairment is lower if the individual initially lacked full utility because of other impairments

Sintonen (1981) obtained ratings from 120 randomly selected Finns of the relative utility of each point on 11 functional scales: raving, hearing, speaking, seeing, working, breathing, incontinence, sleeping, eating, mental functioning, and social participation. The respondents also provided guidance on additive methods for computing a combined utility loss from the discrete losses. The method allows the analyst to go into considerable detail, which is helpful in evaluating a condition where a detailed medical description of the typical course and consequences is available. The lack of a scale related to pain detracts from rating quality, however, especially for conscious states worse than death. The large number of factors and additive weights also mean that impairments which are not systemically pervasive never are rated as very severe, which is inconsistent with the information from other utility scales.

Kind, Rosser, and Williams (1982) developed a two-dimensional scale that is particularly easy to use. One dimension measures disability, where 1 is fully mobile and 8 is unconscious. The second dimension measures distress, where 1 is none and 4 is severe. Median utility values were computed from the non-economic component of British jury awards, which follow an informal schedule. Interviews also were conducted with a non-random sample of 70

subjects including healthy volunteers, doctors, nurses, and patients in medical and mental hospitals. The survey has methodological problems, however, in part because the 10 mental patients provided some extreme ratings that were not censored. It also is inconsistent with both other survey-based estimates of utility loss and the jury award scale. Even the jury award scale's applicability is limited because it does not deal with sensory or mental function. In addition, both the jury and survey data indicate virtually all health states involve utility losses less than 20 percent or more than 60 percent, which seems unlikely and disagrees with other studies.

Kaplan (1982) and Kaplan, Bush, and Berry (1976) provide a utility loss estimates for a scale with simultaneous dimensions of mobility, physical activity, and social activity, as well as linear score adjustments for 36 symptom-problem complexes. The scale, which was the first developed, was calibrated through a population survey in San Diego. It has the major limitation of excluding the possibility that impairments can be worse than or even almost as bad as death. In addition, the symptom-problem complexes sometimes are inconsistent; for example, why should a cough and fever add .007 to utility while a cough alone subtracts .007? Also, more analytic judgment is required to select an appropriate combination of complexes using this scale than to rate diagnoses using any of the other scales.

His et al. (1983) enlisted four physicians--specialists in orthopedics, neurology, plastic surgery, and general surgery-- then divided 476 moderate and severe injuries into their four specialty categories. The physicians defined six functional scales, with impairment levels ranging from 0 to 4: mobility, daily living (self care), cognitive/psychological sensory, cosmetic, and pain. For each injury, the appropriate specialist rated the probable number of weeks of impairment at each level during the first year, and the probable impairment levels during the second through fifth years and thereafter. Separate ratings were done for four age groups. The impact on life expectancy and the need for corrective surgery also were estimated. Using two physicians per injury, Carsten (1986) added physician ratings of some additional injuries and redefined others, arriving at a final set of 432 injuries. Roughly 20 injury experts then used a structured computer exercise to develop weights for combining the ratings on five of the impairment dimensions (self care was omitted) into a total impairment score. Their weighting was adjusted using ratings from an American Medical Association guidebook (1984), which is discussed below. A decision by Carsten, without consulting the physicians, established that no nonfatal injury was worse than death. Luchter (1987) added the days of productivity loss as an impairment measure for minor injuries. Miller, Brinkman, and Luchter (1988) converted the workdays lost for minor injuries into utility loss estimates.

Three sources provide utility estimates for a range of diagnoses rather than for points on functional scales.

The Guides to the Evaluation of Permanent Impairment (American Medical Association, 1984) were developed by rare than 100 physicians. They are intended primarily for assessing impairment through physical examination and provide guidance at a micro level. For example, (a) the impairment associated

with shoulder injuries is estimated separately for the more and less dominant arms and varies with the percentage reduction in range of shoulder rotation, and (b) nine levels of impairment are presented for lung cancer. The guides also provide insight into typical impairment levels for some injuries and illnesses. The guides are perfect. They assume nothing is worse than death. Furthermore, no central control was exerted over the influence specialists on a body system decided that system had overall functioning. Therefore, the average impairment scores for some body systems seem high.

Green and Brown (1978) asked about 100 British university students to rate the relative severity of death, selected injuries, and being unhurt in an accident. Their results are interpreted in this article as indications of the percentage utility loss during the period of disability for acute conditions and of lifetime loss for chronic and irreversible conditions.

Finally, Sackett and Torrance (1978) asked a small random sample of Canadians whether they would rather live their normal lifespan with selected chronic illnesses or live a healthy life but die prematurely. The number of years that people would trade to avoid the different impairments determined the utility losses associated with them. The conditions examined included tuberculosis, depression, renal failure, mastectomy, and an unnamed contagious disease. An important lesson of this study is that the value of an impairments rises with its permanence. More research is needed to determine (a) whether the value of avoiding minor illnesses and injuries is significantly overestimated with the approach suggested in this article and (b) how to adjust the values based on the duration of impairment.

Estimated Investment to Reduce Selected Injuries and Illnesses

Table 1 presents estimates of the utility loss and cost associated with selected injuries. The values in the first column of data are for blindness. The utility loss estimates from Torrance (1982) and Green and Brown (1978) can be used to judge the quality of our estimates using other scales because these studies asked people about the utility loss associated with blindness; the estimates are 37 and 34 percent respectively. The 20 percent value in Card (1980) also is a survey estimate, but may not be representative of the general population because it was based on a small survey of medical personnel. We estimated a 33 percent utility loss from Carsten (1986) by doubling the estimate for losing one eye, so the estimate may be low. Our 39 percent estimate from the Kaplan (1982) scale is for someone who did not drive, walked without physical problems, was limited in choice of work, and wore glasses or had trouble seeing. These two estimates agree with the survey data. The lowest estimate, the 15 percent loss from the Kind, Rosser and Williams (1982) scale, is for a severely limited work choice but no distress. Because this description omits the sensory loss, the utility loss probably is underestimated. Sintonen (1981) provided an adjustment factor for blindness that we used in conjunction with the rating of the impact on functioning to obtain an estimated utility loss of 22 to 24 percent. This estimate may be low because blindness only affects a few aspects of functioning, which means the Sintonen scale unduly constrains the possible utility loss. Viewed from the

perspective of the other estimates, the 85 percent utility loss estimate in the American Medical Association guide is a severe overestimate.

We conclude that the utility loss associated with blindness is probably between 33 and 39 percent. With the $1.95 million dollar value of a life, this range implies typical individuals would be willing to pay between $640,000 and $760,000 to prevent a statistical person among their group from going blind. Data on the average foregone. taxes and transfer payments per blind individual should be added to this value to estimate the SCE.

The second column of data shows the utility loss associated with severe brain damage or lasting unconsciousness. Kind et al. (1982), Torrance (1984), and Green and Brown (1978) measured the utility loss associated with this injury directly and determined it was a fate 8 to 28 percent worse than death. The physician ratings in Carsten (1986) and American Medical Association (1984), which did not allow fates worse than death, rated the utility loss for unconsciousness within 5 percent of the loss for death. Sintonen (1981) found lasting unconsciousness was 3 percent worse than death. Torrance (1984) notes that the visually based rating method used by Sintonen implicitly may have indicated the survey designer expected people to consider death the worst fate, so the 103 percent utility loss may be an underestimate. Kaplan's (1982) scale does not provide good utility loss estimates for severely disabling conditions; for unconsciousness, we estimated a utility loss of 71 percent.

The studies that allow fates worse than death provide the best estimates of utility loss for lasting unconsciousness, with a 116 percent loss seeming most probable. The last three rows of data in Table 1 indicate the medical costs, lost earnings, and other public costs associated with unconsciousness (and other injuries). The medical and earnings data are from Miller, Brinkman, and Luchter (1988), while the public costs are from Miller (1986). His et al. (1983) indicates that severe head injury causes roughly a 5-year reduction in lifespan. If we use a Federal income tax rate of 23 percent (Minarik, 1985) and a state rate of 5 percent (Feenberg and Rosen, 1986), these data can be used with equation (13) to estimate the SCE for a severe head injury at $3,100,000.

As the third column of utilities in Table 1 show, complete quadriplegia is another fate worse than death, with a utility loss of 105 to 114 percent on the three reliable scales, implying a best estimate of 109 percent. The Sintonen scale did not work well here, yielding an estimated utility loss of only 49 percent because its method for combining losses does not allow a large total loss unless the sensory, mental, and rotor systems all are severely affected. Kaplan's scale again worked poorly, while the physician's judged this fate almost as bad as death. Both physician judgment (Carsten, 1986) and interviews with quadriplegics who have adapted to their injuries (Torrance, 1988) indicate the utility loss may decrease over time, leveling out at about 65 percent. Complete quadriplegic reduces expected lifespan by 21.5 years according to His et al, (1983). The estimated SCE for a complete quadriplegic injury is $2,600,000.

Using the scales in Kind et al. (1982), Kaplan (1982), and Torrance (1982), we estimate the utility loss for paraplegia (data column 4) at 50 to 54 percent with incomplete paralysis and 62 to 65 percent with complete paralysis. Paraplegics surveyed by Torrance (1988) and the physicians in Carsten (1986) estimated a slightly smaller loss, around 45 percent. The students surveyed by Green and Brown (1978) and the Sintonen (1981) scale (which did not model paraplegia well) both gave estimates around 29 percent, which are probably too low. As with blindness, the utility loss in the American Medical Association (1984) guides seems much too high, 81 percent. Complete paraplegia reduces expected lifespan by 15.3 years according to His et al. (1983). The best estimate of the utility loss is 50 to 65 percent, with an SCE of $1,300,000 to $1,600,000.

For older people, severe burns (data column 5) are the worst possible fate. They typically spend the rest of their lives bedridden with sufficient pain that they cannot do simple arithmetic. Using the utility scales in Torrance (1982) and Kind et al. (1982), we estimate the utility loss at 137 to 139 percent. The physician ratings, which do not allow fates to be worse than death, yield lower and less credible values. Severe burns shorten lifespan, perhaps by about 5 years. The SCE is about $3.6 million to prevent a person in late middle age from being severely burned.

A broken lower leg (data column 6) typically causes no permanent impairment according to data from the Consumer Product Safety Commission's injury cost model (which also provided the cost data for this injury) and the physician ratings of impairment in Carsten (1986). Four of the five scales we applied suggest a broken leg will reduce utility by 30 to 36 percent in the year it occurs, while Kaplan (1982) yields an excessive estimate of 54 percent. The 34 percent estimate from Green and Brown (1978) was computed as the loss for a broken arm times the ratio of losses for amputation of a leg and an arm. With a one-year utility loss around 33 percent, the SCE for a broken leg is about $40,000.

As the last column in Table 1 shows, our ratings with the Kind et al. (1982), Torrance [1982), and Kaplan (1982) scales suggest typical minor injuries reduce utility by 36 to 38 percent for a few days. These estimates assume the number of lost work days (counting weekends as if they were workdays) equals one half of the impairment days for an employed person who is injured. The 36 to 38 percent range is consistent with survey estimates of 30 percent for a bruise and 40 percent for a sprain in Green and Brown (1978). The Sintonen scale does not work well for minor injuries, yielding a low utility loss estimate of 15 percent, because minor injuries only affect a few aspects of functioning. Including the externality costs, the SCE for a minor injury is about $1,500.

Table 2 shows estimates of the utility loss associated with selected illnesses. The first two columns of data deal with mild and severe angina. Hartunian, Smart, and Thompson (1981) provided the description of angina's impairment impacts that we used and the data on economic costs.

For mild angina, Pliskin, Shepard, and Weinstein (1980) conducted a small survey that indicated the utility loss was 12 percent, in the mid-range of the 10 to 15 percent loss estimate in the American Medical Association (1984) guides. Using the impairment scale in Kind et al. (1982), we estimated the impairment at 0.7 to 16 percent. By assuming that mild angina reduced physical and role function by half a level and also using half the pain score (severe angina caused just one level of reduction on each dimension), we estimated a 16 percent utility loss from the scale in Torrance (1982). This scale, however, did not differentiate impairment as finely as was desirable to analyze a largely asymptomatic condition. Using Kaplan's (1982) scale, we estimated an 18 percent utility loss.

For severe angina, surveys by Miyamoto and Eraker (1985) and Pliskin et al. (1980) yielded utility loss estimates of 30 to 31 percent, comparable to the estimate of 25 to 32 percent we made from the Kind et al. (1982), Torrance (1982), and Kaplan (1982) scales. The loss estimated by the American Medical Association (1984) guides is slightly higher, 35 to 40 percent.

Utility losses of 12 percent for mild angina and 30 percent for severe were used to compute SCEs of $220,000 to prevent a mild case of angina for someone age 55 and $550,000 to prevent a severe case. These estimates seem high, given the economic costs involved.

The third and fourth columns of data give estimates for food poisoning. The estimates were based on the illness descriptions and cost data in Roberts (1985). They apply to cases of salmonella and campylobacter.

Based on Roberts' description, we estimated half the severe cases involve four days of severe discomfort and inability to leave home. We estimated the other half would last six days, with three days of severe discomfort and confinement to a hospital bed and three days of severe discomfort and an inability to leave home or moderate discomfort and extreme weakness. Finally, we assumed all severe cases involve four days with no discomfort, but somewhat reduced strength and resilience. The Kind et al. (1982), Torrance (1982), and Kaplan (1982) utility scales provide consistent estimates of utility loss: 39 to 45 percent over 10 days. During the first three days, both scales indicate patients with severe cases will feel as if they would rather be dead. The SCE estimate is $2,400 to $2,600 to prevent a severe case of food poisoning.

To estimate the utility loss associated with a mild case, we made low and high estimates of impact.

- Low estimate. Assume 30 percent of the cases involve two days of severe discomfort and inability to leave home and the remaining 70 percent involve just 1.5 days of mild discomfort that is not severe enough to prevent the sufferer from going to work. Under this assumption, the average case involves a utility loss (on the Kind et al. (1982) or Kaplan (1982) scales) of 24 to 25 percent for an average of 1.65 days, with an SCE of $140 to $150. The Kaplan (1982) scale suggests an

uncomfortably high 41 percent utility loss for this mild case, ascribing an overly high 33 percent utility loss to mild discomfort that does not prevent someone from working.

- High estimate. Assume 75 percent of the cases involve just 1.5 days of mild discomfort, 25 percent involve two days of severe discomfort, and 5 percent are as severe as the reportable cases. Under this assumption, the utility loss is 25 to 26 percent for an average of 2.1 days, with an SCE of roughly $200.

The SCE per day of mild food poisoning is $85 to $95. By comparison, Berger et al. (1985) obtained a mean willingness to pay to avoid a day of nausea of $91 from 18 respondents, while Gerking et al. (1986) obtained a mean of $409 from five respondents. Gerking believes that his values, and possibly even Berger's, may be higher than people actually are willing to pay. Consistent with his belief, his values exceed the values derived from the impairment scales, even though food poisoning probably is slightly worse than just feeling nauseous.

The utility loss estimates for chronic bronchitis, given in the fifth column of data, were based on a description of the course of illness developed for EPA by Viscusi et al. (1989) and were generated before Viscusi fielded his willingness-to-pay survey. Estimates we made using four scales suggest a utility loss of 35 to 45 percent. The American Medical Association (1984) guides, again high, suggest at least a 50 percent utility loss. Viscusi et al. (1989), based on a survey, estimated the utility loss at 32 percent, close to the range we predicted. Data on externality costs were not readily available to compute the SCE for chronic bronchitis.

The sixth column provides estimates of the utility loss associated with a day in the hospital. The survey by Kaplan (1982) provides a range of utility losses from 41 to 60 percent for hospitalization, "depending on whether the person can move around and perform self care. Sackett and Torrance (1978) obtained an estimate of a 40 to 44 percent utility loss for hospitalization with a contagious disease. The utility loss estimates we made with the Kind et al. (1982) and Torrance (1982) scales were between 55 and 65 percent, possibly a bit high, while the 47 percent loss we estimated with the Sintonen (1981) scale was on the mark. Adding the $550 average charge for a hospital day in 1985 (from the Statistical Abstract, 1988) to a utility loss of 40 to 60 percent, the SCE per hospital day avoided is roughly $700 to $750.

The last column in Table 2 provides estimates of the utility loss associated with receiving regular dialysis for end stage renal disease. Sackett and Torrance (1978) found the loss was viewed as 60 percent by the general public and as 48 percent by those on dialysis. Again high, the American Medical Association (1984) guide estimated a 90 percent utility loss. Using the Kaplan (1982) scale, we estimated the loss at 48 percent. Using the Torrance (1982) scale, we assumed mild physical limitation; some limitation of work, with half the patients largely unable to work; frequent anxiety, but an average number of friends; a disfiguring dialysis shunt; and some discomfort. These assumptions imply a 62 percent utility loss. Without anxiety, the loss

would be 50 percent. The Kind et al. (1982) scale was difficult to apply to this impairment. It suggests a utility loss of 42 to 48 percent, depending on whether the distress level is assumed to be mild or moderate. The costs associated with end stage renal disease derive from unpublished analyses by The Urban Institute, which also indicate that 10 percent of dialysis patients die each year. With a 60 percent utility loss, the SCE is $1,500,000 per case prevented.

Table 3 presents estimates of the utility loss associated with retardation, by severity. No direct survey data are available on this condition. We included it because so many public health problems, among them lead poisoning, fetal alcohol syndrome, malnutrition, foodborne listeriosis, and workplace chemical exposures, can cause children to be retarded. In the future, someone is likely to estimate willingness to pay to avoid retardation, and our estimates will be available for comparison; in the meantime, they may be useful for policy analysis.

We estimated a range of retardation levels, with a utility loss of about 20 percent associated with the need for special education, a severely limited ability to work associated with a utility loss around 50 percent, need for help in self care raising the utility loss to 55 to 60 percent, and very severe retardation raising the loss above 75 percent. The American Medical Association (1984) guides performed well in evaluating retardation, agreeing reasonably well with our ratings from the Torrance (1982) and Kaplan (1982) scales.

A Further Comparison

The impairment estimates in the lineage from His et al. (1983) cover all possible injuries in motor vehicle crashes. Miller, Brinkman, and Luchter (1988) substitute the utility losses for fates worse than death shown here for the physician ratings, then apply the data to estimate the utility loss and associated willingness to pay to avoid a typical injury. For each diagnosis, they compute the present value of future impairment years at a 6 percent discount rate. They then estimate aggregate impairment by multiplying the impairment by diagnosis times data on 1982-1984 injury incidence derived from a sample, compiled by the National Highway Traffic Safety Administration in its National Accident Sampling System. The sample includes all injuries in roughly 30,000 crashes that were reported to the police. The aggregate impairment years next are multiplied times the $120,000 willingness to pay to save a life year. An estimated average willingness to pay to avoid injury of $12,800 results.

Insight into the quality of this $12,800 estimate, and of the impairment estimates, can be obtained from a comparison with estimates of willingness to pay to avoid nonfatal injury in the workplace. Five estimates exist that cover all reported injuries, as opposed to just lost workday injuries. All five derive from hedonic regressions that examine pay differentials for risky jobs. As Table 2 shows, four of the five estimates are between $10,500 and $13,000, satisfyingly close to the estimate from physician ratings of impairment.

The comparison between the willingness to pay to avoid motor vehicle and workplace injuries implicitly assumes that the distribution of injuries is similar in these two settings. That assumption is questionable, because back injuries occur more frequently in the workplace. A special analysis we ran of National Council on Compensation Insurance detailed claims data shows back injuries account for 30 percent of all on-the-job injuries that cause lost workdays, while Luchter (1986) indicates they account for only 5 percent of more-than-minor injuries in rotor vehicle crashes. Thus, the agreement in willingness-to-pay values provides only molest confirmation of the utility loss estimates.

Conclusion

Scales on the utility of functional impairment provide a quick, inexpensive, reasonably consistent, and theoretically supportable way to estimate SCEs for preventing a wide range of diagnoses. Using these methods requires estimating the functional impairment and reduction in lifespan associated with the health status changes. The impacts on transfer payments (including health insurance payments), administrative costs, and taxes on earnings also must be estimated.

The available utility scales yield reasonably consistent values, but these values occasionally seem unreasonably high compared to the economic costs involved (witness mild angina). Pre-planned research validating the utility losses against willingness-to-pay estimates would make it easier to use the scales with confidence.

Scales that do not allow the possibility of fates worse than death should not be used to evaluate severely disabling conditions. Torrance (1982) probably is the most reliable and flexible scale presently available, but lacks utility loss estimates for some aspects of functioning (for example, loss of reproductive capability, sustained pain) and very mild symptoms. The simplistic approach taken by Green and Brown (1978) of asking people to score relative severities of different diagnoses provided surprisingly reliable results. The American Medical Association (1982) guides to permanent impairment, which are based on physician judgment, generally overestimate utility loss.

Table 1
Percentage Utility Loss and Cost Associated With Selected Injuries

Study	Blind	Severe Head	Quad	Para	Severe Burn (age 45+)	Broken Lower Leg	Minor Injury@
Kind, Rosser, & Williams	15	108	114	52-65	137	31	38
Kaplan	39	71	66	50-64		54	36
Torrance	37*	116	105	54-62	139	34	37
rehabed patients			65*	45*			
Green & Brown	34*	128*	109*	29*		30	30-40*
Card	20*						
Sintonen	22-24	103	49	29			15-16
Carsten	33*	93-100*	85-86*	42-45*	91*	36	
Am Med Assoc	85*	95*	99	81	95*		
Medical Cost	DK	680,000	390,000	235,000	450,000	200	285
Productivity Loss	DK	400,000	210,000	160,000	100,000	1,350	280
Legal, Admin, Transfer	DK	60,000	60,000	35,000	60,000	DK	DK

@ Average daily utility loss until recovery, which occurs in less than 1 year.
* Direct measurement.

Table 2
Percentage Utility Loss and Cost Associated With Selected Illnesses

Study	Angina Mild	Angina Severe	Food Poisoning@ Severe	Food Poisoning@ Mild	Chronic Bronchitis	Day in Hospital@	ESRD
Kind et al.	.7-16	25-31	45	24-25	23-37	61-62	42-48
Torrance	16	32	39	25-26	34-45	55-65	62
Kaplan	18	32	45	41	45	41-60*	48
Sintonen					30-36	47	
Sackett & Torrance patients						40-44*	60* 48*
Miyamoto & Eraker		30*					
Pliskin et al.	12*	31*					
Viscusi et al.					32*		
Am Med Assoc	10-15*	35-40*			50+		90*
Medical Cost	2700		60	1000	DK	500	250,000
Productivity Loss	50		30	300	DK	50	90,000
Transfer & Admin	0		0	DK	DK	DK	10,000

@ Average daily utility loss until recovery, which occurs in less than 1 year.
* Direct measurement.

Table 3
Utility Loss Associated with Retardation

Condition	Util Loss	Source
Very severely retarded	83	Torrance
	75+	Am Med Assoc
Retarded needing help with care	57	Kaplan
	55	Torrance
	55-75	Am Med Assoc
Moderately retarded with self-care	42-51	Kaplan
	52	Torrance
	25-50	Am Med Assoc
Mildly retarded	33	Kaplan
	20-32	Torrance
	23	Sintonen
	10-20	Am Med Assoc

Table 4
Willingness to Pay to Avoid Non-fatal Workplace Injuries
(1985 After-tax Dollars)

Study	Value
Butler (1983)	$10,500
Dillingham (1983)	$17,000-$26,000
Olson (1981)	$12,000-$13,000
Smith (1983)	$11,000
Viscusi (1978)	$12,000-$21,000

Note: Values were converted to after-tax dollars using the method described in Miller (1986).