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Valuing chronic disease for heterogeneous populations: the case of arthritis

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Abstract

Current techniques for measuring morbidity losses have been criticized as being subjective, inflexible, impractical, and subject to bias. In this paper we present a feasible approach for the assessment of improved quality-adjusted life-year (QALY) estimates for chronic conditions that affect heterogeneous populations. An ordered probit model using data from the National Health Interview Survey (NHIS) is used to calculate expected QALY losses from arthritis for distinct population subgroups. Our results indicate that a failure to account for population heterogeneity can lead to biased health loss estimates.

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1. Introduction

The valuation of morbidity has received considerable attention in recent years. A primary reason for this attention is that the demand for accurate health loss estimates has risen with the growing influence of economics in Federal policymaking.² In response to this demand a number of methods have been devised to estimate the value of health losses. These methods, while useful, have generally been limited in their abilities to measure losses for chronic conditions and distinct populations. In this paper we offer a method of estimating quality-adjusted life-year (QALY) losses for chronic conditions affecting heterogeneous populations. To test our method we focus on the effects of arthritic conditions that result from foodborne illness.

We begin with a discussion of how arthritis may be prevented and how Federal agencies are using arthritis prevention as a rationale for regulations designed to promote public health. Next, we present a model of optimal prevention that illustrates how health loss values are used in a policy context. An analysis of the conditions leading to optimal prevention allows us to model how utility loss from arthritis differs for distinct populations.

Following a discussion of alternative valuation techniques we estimate the value of arthritis using a modified method of measuring quality-adjusted life-years (QALYs) that was developed by Cutler and Richardson (1999). We then use data from the National Health Interview Survey (NHIS) to calculate the marginal effects of arthritis on self-

² In 1993 the President signed Executive Order 12866 which mandated that executive branch agencies conduct economic analyses for all major rules. More recently, in 2000, the Truth in Regulating Act (P.L. 106-312) gave Congress the ability to request an independent review of the economic implications of major rules.

assessed health status. Unbiased parameter estimates are generated using an ordered probit model specified to include controls for demographics and co-morbidity.

Next, we compare our results to those that have been estimated using other techniques. We conclude our study by estimating and aggregating the expected health loss from arthritis that results from foodborne illness.

2. Arthritis Prevention and Public Health

As one of the most widespread public health problems facing the United States today arthritis makes an interesting case study for our method. The Centers for Disease Control and Prevention (CDC) estimates that over 42 million Americans were afflicted with arthritis in 1996 and 60 million will have arthritis by 2020 (CDC 1999). Of these persons, 42% are limited in their activities because of arthritis.

Public sector interest in arthritis has traditionally been limited to medical research and treatment. Nonetheless, it has become increasingly evident that preventative measures can reduce the incidence of arthritis. As a result, policymakers are now more interested in regulatory actions that result in public health benefits from arthritis reduction.

The growing awareness of preventable risk factors for arthritis is reflected in Federal rulemaking that increasingly targets the reduction of arthritis and other musculoskeletal disorders. In particular, regulatory impact analyses have made increasing use of measured health benefits for averted cases of arthritis. The role of foodborne illness as a cause of arthritis has been explicitly recognized in regulatory impact analyses at the Food and Drug Administration (FDA) since 1998. More recently, similar analyses have been used for proposed regulations emanating from the U.S. Department of Agriculture's Food

Safety Inspection Service and the Occupational Safety and Health Administration.

Inspection of rules in which the value of arthritis reduction was estimated reveals that arthritis often plays a dominant role in benefits estimation.³

A number of risk factors have been associated with arthritis. Some of these factors, such as sex, age, and genetic predisposition, are clearly not preventable. Other risk factors, such as obesity, joint injuries, repetitive joint stress, and infection are potentially controllable.

A typical regulatory action aimed at reducing the incidence of arthritis focuses on reducing or eliminating one risk factor for arthritis. If all risk factors affected the onset and progression of arthritis similarly it would be sufficient to use one estimate of the value of the expected health loss for all risk factors. However, in the case of arthritis each risk factor affects distinct populations in different ways. For example, an individual who gets arthritis through repetitive joint stress often engages in damaging behavior for years before arthritic symptoms are experienced. As a result, an accurate estimate of the economic loss accruing to the repetitive action must be discounted and adjusted for the fact that such an individual may be older than the typical arthritis sufferer. Alternatively, an individual who is afflicted with arthritis as a result of exposure to a foodborne pathogen is likely to be younger and to experience symptoms within weeks of the exposure.

The presence of such distinct populations of potential arthritis sufferers that are affected by discrete classes of prevention activities argues for a valuation methodology that explicitly recognizes the heterogeneity of the population. In the absence of such an

³ For example, the FDA estimates that over 80% of all benefits from the reduction of Salmonella Enteritidis are due to a reduction in arthritis cases.

estimation method, benefits estimation for policy purposes is likely to be systematically biased.

3. Theory

In this section we specify a model of preventative expenditures for the case of arthritis. Optimization of this model depends on the efficient estimation of utility loss from arthritis. The conditions for optimization of the prevention model are then used to show how the mean expected utility loss for arthritis is affected by population heterogeneity.

Optimal Preventative Expenditures

A human health risk reduction benefit model can be used to illustrate the efficacy of preventative measures aimed at reducing the probability that an individual will contract arthritis.⁴ For the individual in question we assume that utility depends on arthritis status, consumption, and other variables. This can be modeled as

$$U = U(A, C, X), \quad (1)$$

where U is expected utility, A is an indicator variable for arthritis, C is a measure of consumption, and X is a vector of exogenous personal characteristics. Utility is assumed to decrease with the presence of arthritis ($\partial U/\partial A < 0$) and increase at a decreasing rate with consumption ($\partial U/\partial C > 0$, $\partial^2 U/\partial C^2 < 0$).

Arthritis incidence is affected by expenditures on preventative care (E). The cost of regulating foods to decrease their contamination with pathogens associated with reactive

⁴ The basic model is from Tolley, Kenkel, and Fabian 1994.

arthritis is one such expenditure. Personal characteristics (X) such as age, occupation, and personal tastes play a role in how limiting a case of arthritis will be for an individual.

In equation 2 we model welfare as the expected value of utility with arthritis U_A and without arthritis U_H . Arthritis (A) has a direct negative effect on utility. In the healthy state (H) arthritis takes a value of 0 and is consequently omitted from the model.

$$U = p(E,X) \times U_A(A, C_A(E), X) + (1-p(E,X)) \times U_H(C_H(E), X) \quad (2)$$

In this model the choice variable for the individual is preventative expenditures to avoid arthritis. These expenditures affect both the probability that an individual will be affected by arthritis (p) and the individual's consumption of all other goods with arthritis (C_A) and without arthritis (C_H).

Taking the first order conditions of equation 2 leaves us with:

$$p \cdot \frac{\partial U_A}{\partial C_A} \cdot \frac{\partial C_A}{\partial E} + (1-p) \cdot \frac{\partial U_H}{\partial C_H} \cdot \frac{\partial C_H}{\partial E} = \frac{\partial p}{\partial E} \cdot (U_H - U_A). \quad (3)$$

We can simplify equation 3 by recognizing that the marginal effect of preventative expenditures on consumption is not affected by arthritis status ($\partial C_A/\partial E = \partial C_H/\partial E$).⁵

Furthermore, we assume that the marginal utility of consumption is the same in both states ($\partial U_A/\partial C_A = \partial U_H/\partial C_H$).⁶ Consequently, equation 3 can be rewritten as:

$$\frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial E} = \frac{\partial p}{\partial E} \cdot (U_H - U_A). \quad (4)$$

⁵ Although the marginal effect of preventative expenditures on consumption is equal in both health states, we expect that, given a fixed set of preventative expenditures and personal characteristics, arthritis sufferers will consume less than non-sufferers, or $(C_A|E, X) < (C_H|E, X)$. This is a result of our expectation that income and, hence, consumption falls with the onset of arthritis because of its adverse effect on productivity.

⁶ The actual effect of arthritis on the marginal utility of consumption is unclear. Expected utility theory suggests that as consumption falls the marginal utility of consumption rises. However, Viscusi and Evans (1990) showed that poorer health status is associated with a lower marginal utility of income. Which of these effects dominates is unclear in this case. As a result, we assume that $\partial U_A/\partial C_A = \partial U_H/\partial C_H$.

Equation 4 gives us the usual result that preventative expenditures are optimized when the marginal cost of forgone consumption equals the marginal benefits from risk reduction and health gains.

Cost-benefit analysis of health regulations (CBA) generally does not achieve this level of precision. Instead, the summary measure from a CBA is often a comparison of aggregate changes in social costs and benefits due to a given program.⁷ A program is said to pass the cost-benefit test if:

$$\frac{\Delta C}{\Delta E} < \frac{\Delta p}{\Delta E} \cdot (U_H - U_A). \quad (5)$$

The three components of equation 5 are cost estimation, risk assessment, and utility loss estimation. Economists have primary responsibility for the derivation of the first and third terms of this equation. Though not always easy, the estimation of costs is not a particularly controversial area of economics. There is, however, great disagreement among economists regarding the estimation of utility loss.

Despite the differences in equations 4 and 5, both rely on accurate estimation of utility loss from arthritis ($U_H - U_A$).

The Heterogeneity of Utility Loss from Arthritis

The theoretical estimation of optimal preventative expenditures is straightforward. The effects of a heterogeneous population on the estimation of utility loss ($U_H - U_A$) are less clear. While it is generally recognized that the effect of a condition on health may differ for distinct individuals, most empirical studies dodge this issue by assuming that

⁷ When cost-benefit analysis is used the focus of the analysis is on social costs and benefits as opposed to individual utility maximization. Consequently, $U_H - U_A$ includes the external cost of medical care in equation 5, but not in equation 4.

the mean estimated utility loss is an adequate measure for a given sample population.

Unfortunately, most estimated QALYs are applied to populations that are demographically dissimilar from the originally surveyed population.

The heterogeneous nature of individual utility losses can be examined by exploring the effects of perceived arthritis severity on utility. First, we redefine utility loss to equal:

$$U_H(G, Y) - U_A(S(G), G, Y), \quad (6)$$

where S is a measure of perceived arthritis severity, G is the individual's age⁸, and Y is a vector of other personal characteristics.

The marginal effect of age on utility loss is:

$$\frac{\partial U_H}{\partial G} - \left(\frac{\partial U_A}{\partial S} \cdot \frac{\partial S}{\partial G} + \frac{\partial U_A}{\partial G} \right). \quad (7)$$

Equation 7 illustrates a number of interesting effects. *Ceteris paribus*, in both arthritis states, we expect the aging process to negatively affect health and, consequently, utility ($\partial U_H/\partial G < 0$, $\partial U_A/\partial G < 0$). The net direct effect of age on utility loss due to arthritis ($\partial U_H/\partial G - \partial U_A/\partial G$) is an empirical question that we explore below.

Aging also affects utility loss through its impact on arthritis severity. It is safe to assume that increased arthritis severity results in a utility loss ($\partial U_A/\partial S < 0$). The effect of age on severity ($\partial S/\partial G$) is less clear. For a progressive case of arthritis we would expect the deterioration of joint tissue to result in increasing medical severity with age. This is reflected in the observed increase in arthritis limitations with age, as represented in figure 1. However, for a given level of joint deterioration, the marginal perceived severity of

⁸ We use age as a measure of heterogeneity in this example. However, failure to adjust for other relevant population measures would lead to biased estimates of utility loss.

arthritis is likely to diminish with age because of the increasing ability to adapt to health problems and the presence of other limiting conditions.

The assumption that a single utility loss estimate can be used for different aged populations implies that $\partial U_H/\partial G = \partial U_A/\partial G$ and $\partial S/\partial G = 0$ at all ages. As we will show below, this is not the case. Therefore, a perfectly acceptable estimate for a given population is likely to be biased when applied to a demographically disparate population.

4. Methods of Measuring Health Losses

The importance of obtaining accurate arthritis values for economic analyses is illustrated in equations 4 and 5. In this section we examine theoretical and practical considerations of alternative techniques for measuring health loss. A theoretically correct measure is one that, if free from bias and measurement error, closely approximates the individual's willingness to pay (WTP) to avert a given health loss plus any external costs of that loss. A practical measure is one that is feasible given limited time and resources and that is likely to return values free from bias and measurement error.

A number of methods have been developed to measure the value of health losses. The cost of illness approach, contingent valuation, hedonic pricing models, and valuation of quality-adjusted life-years (QALYs) have all been suggested as potential measures of the social cost of health losses. The fact that each of these methods currently has proponents suggests that there is no one method that has proven itself to be both theoretically and practically superior to the others.

The cost of illness approach has been widely used in economic analyses produced by the Federal government. The attractiveness of this method stems from the fact that it is

easy to estimate, is based on the use of market data, and is unlikely to result in grossly exaggerated benefits estimates. Nevertheless, the cost of illness measure does not theoretically approximate a WTP measure because it does not include non-market values for pain and suffering. Therefore, estimates derived using the cost of illness approach are generally seen as lower bound measures for health losses.⁹

Contingent valuation (CV) is another measure that many believe to be appropriate. This method relies on survey responses to WTP questions. Because the survey questions directly ask for an individual's willingness to pay, CV may be the most theoretically valid means of assessing individual WTP.¹⁰ There are three major drawbacks to this method. First, WTP measures that are derived using CV are subject to a number of biases. Hypothetical bias, embedding, warm glow effects, and strategic action are all potential problems with CV studies.¹¹ A second drawback of CV studies is the cost and amount of time required to conduct a high quality study. A final drawback of CV studies is that the estimates derived from such studies are not bounded. When this is the case, the absence of meaningful budget constraints and warm glow effects could lead to grossly exaggerated value estimates (Arrow et. al. 1993).¹²

⁹ Kuchler and Golan (1999) suggest that cost of illness is not a lower bound for WTP because insurance pays a large portion of medical costs. This is a correct assessment for individual WTP. However, the social cost of a health loss includes the external cost the loss to others. For policy decisions the social cost of a health loss is the lower bound estimate for health losses.

¹⁰ Based on comments made at the Valuing the Health Benefits of Food Safety Conference, September 13-14, 2000 (<http://www.ers.usda.gov/Publications/mp1570/>).

¹¹ Hypothetical bias exists because individuals answering the survey know that their stated value for a given policy or good is not an obligation of payment. The embedding effect leads to an upward bias in WTP estimates when individuals making a valuation of a particular good or policy use the opportunity to express their feelings about a whole class of related goods or policies. Similarly, the warm glow effect occurs when individuals overestimate the value of a good or policy because doing so makes them feel good about themselves. Finally, strategic action can lead to biased results when individuals that know their own valuation is not consistent with that of the majority exaggerate their valuations to bring the mean valuation closer to their own.

¹² In an experiment with asthma drugs Blumenschein et. al. (2001) found that the dichotomous choice contingent valuation method does overestimate the willingness to pay for health improvement.

Hedonic pricing is another attractive method of assessing the value of health losses. This method derives the implicit price of health or safety from price differentials between products with varying levels of safety. This method has the advantage of being based on market data. The main drawback of this approach is that markets for safety do not always exist, especially when consumers and producers do not adequately understand the health risk in question. Given that regulation is generally most desirable when such markets do not exist or do not operate efficiently, we do not believe that this method will be useful in most cases.¹³

A final method that has been used in evaluating health losses involves the measurement of quality-adjusted life-years (QALYs). A number of means for measuring QALYs have been constructed including the rating scale, time-tradeoff, and standard gamble methods. A common element of each of these methods is the discrete and subjective assessment of the health consequences of a specific condition.

There are advantages to using QALYs. First, with this method the effect of a condition on health is generally estimated to be between zero (utility in the full health state) and one (utility in death). This boundary limits potential bias that might arise due to the survey format. Second, QALYs include losses due to pain and suffering, which is especially important for conditions such as arthritis where the largest share of utility loss is due to pain and suffering. Finally, QALYs are relatively easy to compute. Catalogs of

¹³ Cockburn and Anis (1998) illustrate the weakness of the hedonic method in their analysis of arthritis drugs. The results of this study actually showed a negative correlation between efficacy and price and a positive correlation between toxicity and price. The authors conclude that the market for these drugs is not sensitive to economic considerations of consumers.

QALY losses for various symptoms and disability levels can be used to quickly estimate the loss associated with a given condition.¹⁴

QALYs are also subject to a number of shortcomings. One drawback of QALYs is that many QALY estimation techniques are subject to biases similar to those found in CV studies. These biases are exacerbated when persons not affected by the condition in question are answering hypothetical questions relating to pain and suffering.

Some types of QALYs are also limited in what they measure. While CV studies include the full value of a condition to the affected individual, QALYs based on assessments of health status do not take into account the direct monetary cost of illness and, in some cases, productivity losses from the condition in question. These values must be added later.

Another limitation of traditional QALYs is that they are unlikely to properly account for adaptation and scale of reference effects. Adaptation refers to a decreasing perceived health loss that is the result of the afflicted individual adapting their behavior to minimize the adverse effects of the condition. An individual's scale of reference refers to the traits (such as age, other health problems, and other demographic variables) that affect his or her perception of the impact of a health loss. For example, a 90-year-old with cancer who has had chronic arthritis for 50 years will value arthritis at a different rate than a 22-year-old factory worker who has recently acquired the disease. Consequently, unless the QALY loss for a disease is estimated from a population that closely matches the population the QALY will be used to describe, adaptation and scale of reference effects will lead to a biased estimate of the QALY loss associated with the disease.

¹⁴ See Kaplan et. al. (1993)

A Modified QALY method

An alternative to the methods described above is a modification of the QALY method developed by Cutler and Richardson (1999). Using data from the National Health Interview Survey (NHIS), Cutler and Richardson were able to calculate the marginal effects of a given condition on self-assessed health status. We extend their research by explicitly addressing issues related to population heterogeneity.

One advantage of the modified QALY over other methods is that it is not subject to the biases inherent in CV and traditional QALY surveys. Hypothetical bias does not exist because individuals are reporting how they feel, not how they would feel if they had a given condition. Strategic bias and warm glow effects are avoided because individuals answering questions for such a comprehensive national survey are unlikely to know how the results will be used. Finally, the problem of embedding is eliminated with this method by including dummy variables for co-morbidities.

Another important advantage of the modified QALY over other methods is that we can use it with large, nationally representative data sets. CV and traditional QALY survey results are generally characterized by a relatively small number of observations, limited data on co-morbidities, and limited demographic information. As a result, the samples derived from these surveys are less likely to be representative and are less likely to be useful for examining the effects of population heterogeneity on valuation estimation. The modified QALY method does not have these limitations. The richness of data from large data sets such as the NHIS facilitates the examination of population heterogeneity.

A final advantage of our method is that modeling the population as heterogeneous allows us to account for adaptation and scale of reference effects. Thus, while Groot (2000) suggests that the Cutler and Richardson (1999) study likely suffers from adaptation and scale of reference bias, our refinement mitigates this problem by specifically addressing population heterogeneity.

5. The Empirical Model

The model we use to estimate QALYs is illustrated in equation 8.

$$h_i^* = \beta'x_i + \varepsilon_i \quad (8)$$

An individual's basic health status (h_i^*) is dependent on a vector of demographic factors and health conditions x_i . Important independent variables include an arthritis variable which is interacted with other relevant variables and variables to account for co-morbidity. We assume that measurement errors ε_i are normally distributed.

No perfect measure of h_i^* exists, so we use a measure of self-assessed health status (h_i) where an individual rates their health as excellent, very good, good, fair, or poor. As equation 9 shows, cut points (μ) define the relationship between self-assessed health status and the individual's true underlying health status.

$$\begin{aligned} h_i &= 0 \text{ if } h_i^* \leq \mu_0 \\ h_i &= 1 \text{ if } \mu_0 < h_i^* \leq \mu_1 \\ h_i &= 2 \text{ if } \mu_1 < h_i^* \leq \mu_2 \\ h_i &= 3 \text{ if } \mu_2 < h_i^* \leq \mu_3 \\ h_i &= 4 \text{ if } \mu_3 < h_i^* \leq \mu_4 \end{aligned} \quad (9)$$

Based on the structure of the dependent variable, self-assessed health status (h_i), we use an ordered probit model to estimate the parameter values for arthritis.

We can use the parameter values estimated using this method to calculate QALY losses. The first step in calculating these losses is to estimate the marginal effect of arthritis on health net of any interaction effects. Next, we divide the marginal effect by the difference between the higher and lower bounds of estimated cut points to scale the parameter values.¹⁵ This is necessary because the dependent variable in this case takes a value between 0 and 4 while QALYs take values between 0 and 1. The resulting value is a usable QALY loss estimate.

6. Data

To estimate the model we use data from the National Health Interview Survey (NHIS). The NHIS is a multistage probability sample of the civilian, noninstitutionalized population of the United States. Questions in the core components of the NHIS remain the same in each year that the survey is administered. Therefore, we are able to use NHIS data for all of the years between 1990 and 1996.

Not all observations from the NHIS data sets are used in our analysis. Data is limited to those respondents that have a record in the NHIS 'person' file. Also, those observations for which health status is unknown are omitted. Finally, we limited

¹⁵ Mathematically, the QALY loss is estimated as $QALY = \text{Arthritis Coefficient} \div (\text{Cut } 4 - \text{Cut } 1)$.

observations to those for which detailed questions about skin and musculoskeletal problems were asked.¹⁶ Our analysis used a total of 90,110 observations.

Observations with independent variables coded as 'unknown' are included in the analysis. For most variables fewer than 1% of the observations are coded as unknown. In these cases we generally use the mean value of the variable in question as a proxy. Family income is a notable exception. Over 15% of the observations are coded as unknown for family income. To correct for this we use imputed estimates of income from the NHIS Imputed Annual Family Income (1990-1996) data set.

In table 1 we present descriptive statistics for the variables that are used in our analysis. Self-assessed health has a mean value of 2.76 over the range 0 to 4. This value implies that the typical U.S. resident finds himself or herself to be generally healthy. A total of 16.7% of respondents claim to have some form of arthritis, about the same as CDC's estimate that nearly one in every six persons has arthritis.

Dummy variables covering all medical conditions reported by respondents' are also included in our analysis. The prevalence of other conditions range from 0.2% of respondents suffering from an intestinal infectious disease within the last two weeks to 47.3% of respondents being classified as overweight. Because perceived health status is a function of present and expected future health problems we incorporate both chronic and acute conditions in our analysis. Because there is a correlation between arthritis and other conditions, the failure to include other conditions in an analysis of the marginal effect of arthritis on health is likely to lead to an overestimation of arthritis QALY losses.

¹⁶ Information for all conditions were collected for all persons. However, more probing questions regarding arthritis were asked of persons on the skin and musculoskeletal list. Limiting the sample to persons on this list ensures that all arthritis sufferers are adequately accounted for in our analyses. All condition lists are randomly assigned in the NHIS.

As stated above, the ability to correct for co-morbidity is one of the greatest advantages of this approach.

The demographics of the sample that is used are not an exact match with the population as a whole.¹⁷ Oversampling of selected subpopulations has resulted in a sample that is older and more likely to be composed of minorities. Dummy variables are included for these subgroups to eliminate the potential for sampling bias in our QALY estimates.

7. QALY Losses from Arthritis

In table 2 we present health status equations for four alternative specifications of our model. In each specification self-assessed health status is the dependent variable, while arthritis and demographic variables are the independent variables. In addition, independent variables are included for survey year and proxy responses. Condition variables are included in the second, third, and fourth specifications to correct for co-morbidity. The third and fourth specifications also include a dummy variable for age. As discussed above, age is a useful variable for the examination of the heterogeneous nature of arthritis sufferers. The estimated coefficients for all of the standard variables have the expected signs and most are significant.

Of particular importance for this paper are the arthritis variables. In all cases there is a statistically significant negative correlation between arthritis and health status. In the first two specifications the marginal effect of arthritis on health is fully embodied in the arthritis variable. As expected, the estimated QALY loss in the absence of controls for

¹⁷ See the Census bureau homepage for comparison.

co-morbidity is greater than that estimated in conjunction with controls for co-morbidity. The coefficient on arthritis for the first equation is -0.47 , which estimates a QALY loss due to arthritis of 0.18 . In the second equation an arthritis coefficient of -0.34 implies a QALY loss of 0.12 .

The second equation is an adequate specification for a homogeneous population. To illustrate the implications of population heterogeneity on expected utility loss we include a variable that interacts age with arthritis in the third equation. We find that health losses due to arthritis generally decrease with age, implying that $\partial S/\partial G < 0$. Consequently, the effects of age on severity result in lower utility losses for older arthritis sufferers.¹⁸ We estimate that arthritis results in a QALY loss of from 0.17 at age 30 to 0.11 at age 60. At the mean age of the sample (44.6) we estimate a QALY loss of approximately 0.14 .

One interpretation of the results in the third equation is that individuals adapt to the chronic pain they are faced with. Alternatively, the decreasing effect of arthritis on health status may be solely due to the increasing role that other age-related conditions play in activity limitation.

In the fourth equation we test these theories by including a dummy variable for individuals that have experienced arthritis symptoms for more than five years (Onset5yr). We find that persons who have had arthritis symptoms for more than five years suffer more than persons who have recently been afflicted with arthritis. We continue to find that older arthritis sufferers experience fewer health losses from arthritis. These results suggest that suffering due to arthritis increases over time due to the progressive nature of

¹⁸ This result is a consequence of the fact that as people age they are more likely to be afflicted with multiple conditions. The marginal disutility of any one condition diminishes with the addition of other conditions.

the disease. At the same time, the marginal effect of arthritis on overall health status diminishes with age due to the increased prevalence of other health and physical limitations that affect older persons.

Other marginal effects are consistent with our expectations. Health status falls at a decreasing rate with age, is higher for men, is lower for minorities, increases with income and education, and is higher for persons who work.¹⁹

Other Factors Affecting QALY Losses

The method presented above allows us to adjust our estimates of economic loss from arthritis for any of a number of population-specific factors that influence individuals' valuations of morbidity. For the case of arthritis we have found that age and duration of illness are significantly correlated with estimated QALY losses. However, a number of other factors may also be correlated with utility loss due to arthritis. In table 3 we present QALY losses for selected population subgroups. In all cases the age effect is significant and similar to the effect for the full sample. The differences between subgroups are less significant. We conclude that, for arthritis, age appears to be the most important variable to correct for.

¹⁹ Johannesson and Johansson (1997) found that, in a survey, individuals valued life years and QALYs for young persons more than for older persons. This may, in part, arise from an exaggerated recognition of the lower expected health status of older persons.

Among others, Gerdtham and Johannesson (2000) recently showed that the expected value of QALYs increases with income.

Butler et. al. (1987) suggest that persons who do not work are likely to underestimate their true health status. The inclusion of a dummy variable for persons who work should mitigate this potential problem.

Comparison of QALY Loss Estimates

A number of methods have been used to estimate QALY losses in economic analyses. In table 4 we present estimates for QALY losses as estimated in three studies. Zorn and Klontz (1998) published an analysis of the cost of arthritis that results from foodborne illness using traditional QALY estimation methods. Cutler and Richardson (1999) used a method of measuring QALYs similar to the one we use to measure the health status of the United States. Finally, we estimate QALYs lost due to arthritis for both the population as a whole and for selected ages.

Zorn and Klontz (1998) were the first to calculate an economic value of QALY losses attributable to chronic arthritis. Using an estimate based on a catalog of symptoms they estimated a QALY loss for chronic arthritis equal to 0.29 for all age groups. The estimated QALY loss depended on the authors' subjective assessment of functional status and symptom severity for a typical case of arthritis. As mentioned above, the utility losses generated by this method are likely to be biased upwards because it ultimately relies upon a CV-like survey of persons with given symptoms and functional limitations.

In 1999 Cutler and Richardson used a method similar to the one used in this paper and found a QALY loss for chronic arthritis equal to 0.21. Despite using a similar method the Cutler and Richardson estimate for QALY losses is significantly higher than ours. There are three reasons for this. First, as medical technology advances, the pain and suffering that are attributed to various medical conditions is expected to fall. In fact, one of the findings of the Cutler and Richardson paper was that the expected health loss due to chronic arthritis fell from 0.26 in 1980 to 0.21 in 1990. The data used in this paper was

collected between 1990 and 1996. As a result, we would expect 0.21 to be an overestimate of the actual QALY loss from chronic arthritis.

Second, the Cutler and Richardson study did not correct for all relevant demographic variables.²⁰ This is particularly important given that the NHIS is not a truly random sample. If no corrections are made the oversampling of selected subpopulations is likely to lead to biased estimates. Also, it is important to remember that we are not trying to estimate the difference between health with a given condition and perfect health. Instead, we are trying to estimate the difference between what an individual's health would have been in the absence of a condition (their reference point) and that person's health with the condition. Failure to adequately correct for all relevant demographics is likely to lead to reference point bias.

Finally, the Cutler and Richardson estimate is likely to be an overestimate because they included observations from persons who were not asked specifically about musculoskeletal conditions. Persons who have a mild form of arthritis are less likely to reveal that fact when they are not prodded to do so. For that reason the Cutler and Richardson paper is less likely to pick up mild cases of arthritis. A subsample of serious arthritis cases is likely to yield greater QALY losses than the full sample of all arthritis sufferers would.

8. A Case Study: Arthritis from *Salmonella Enteritidis* in Eggs

An individual infected with the *Salmonella Enteritidis* (SE) bacteria may develop chronic reactive arthritis. Epidemiological evidence suggests that this sequelae affects

²⁰ Among the demographic variables that the Cutler and Richardson paper does not include are education, income, working status, marriage status, and regional dummy variables.

about 2.4% of the population of SE infected persons (Zorn and Klontz 1998). There is no evidence that age or severity of illness affects the likelihood of arthritis sequelae.

QALY Losses Due to SE-Related Arthritis

To calculate a QALY loss estimate for individuals that develop arthritis we construct the following model. For each age group the expected discounted lifetime QALY loss is estimated as

$$Q_c = \sum_{G=I_c}^{LE_c} \frac{QALY(G)}{(1+r)^{(G-I_c)}} \quad (10)$$

where Q_c is the discounted lifetime QALY loss, G is age, I_c is age of arthritis incidence, LE_c is life expectancy, $QALY(G)$ is the age specific QALY loss, c is an index variable for age group, and r is the discount rate.

In table 5 we present our calculations of Q_c for five representative age groups.²¹ Lifetime QALY losses due to arthritis (Q_c) range from 0.79 for adults over 70 to 5.14 for children under the age of 10. The weighted average number of QALYs lost due to SE-related arthritis is estimated to be 3.71.²²

Also presented in table 5 is the QALY loss based on the assumption of homogeneous health effects. In this case the average arthritis sufferer who acquired his or her condition from a SE infection at the age of 25 will lose 3.17 QALYs as a result. Consequently, the assumption of a homogeneous population that is not affected by adaptation or scale of

²¹ The average age of incidence is estimated to be 75 for the over 70 years group and is assumed to be the midpoint of the age range for all other groups. The life expectancy at each average age is taken from the CDCs National Vital Statistics Report (Anderson 2001). $QALY(G)$ is calculated using the results from table 2. A discount rate of 3% is used in our calculations.

reference effects results in total lifetime QALY losses due to SE-related arthritis that are underestimated by almost 15%.

Valuation of QALY Losses Due to SE-Related Arthritis

The monetization of QALYs is controversial. Medical practitioners and many economists prefer the use of cost effectiveness analysis because it allows for the recognition of tradeoffs without explicitly placing a dollar value on QALYs lost. Nevertheless, the total economic value of QALYs lost can only be estimated by using some method of valuation that converts QALYs from health losses to dollar losses. As a result we choose to present explicit valuations for the purpose of illustrating the magnitude of the problem faced.

If 229,000 persons become ill each year due to SE, and 2.4% of these persons develop chronic arthritis as a result of their illnesses (Zorn and Klontz 1998), there will be approximately 5,500 new cases of SE-related arthritis each year. As estimated above, the average case of SE-related arthritis results in the loss of 3.71 QALYs. The total value of QALYs lost as a result of new cases of SE-related arthritis is simply $5,500 \times 3.71 \times \$$ per QALY.

In table 6 we estimate the total value of QALY losses from SE-related arthritis using three methods of valuing QALYs. These methods are based on the cost-effectiveness, value of a statistical life, and willingness to pay literatures.

The first estimate is based on the use of QALYs in cost effectiveness analyses. A value of \$100,000 per QALY is often used as a criterion for cost effectiveness. If we

²² The percent of SE cases in each age category is used as that age category's weight. Data from the Public Health Laboratory Information System, as reported by the CDC (Division of Bacterial and Mycotic

assume that a QALY is therefore valued at \$100,000, the total value of SE-related arthritis would be equal to \$2 billion per year.

The next estimate we examine is based on the value of a statistical life. If a statistical life is valued at \$5 million, the properly discounted value of a statistical life year is approximately \$230,000 (Moore and Viscusi 1988). As a result, the total social cost of SE-related arthritis is estimated to be \$4.7 billion.

Our final estimate for the value of a QALY is based on the concept of willingness to pay. Johnson et. al (1997) suggested that QALYs could be valued by comparing the results of contingent valuation studies for health losses to QALY loss estimates. Using the results of this study we estimate that the implicit willingness to pay to avoid a loss of one QALY ranges from \$1,700 to \$143,000. This translates into a value for SE-related QALY losses totaling \$30 million to \$2.9 billion.

9. Conclusion

The limitations of current methods used to estimate non-monetary health losses for chronic disease are well documented. Notwithstanding these limitations, the increasing use of health values in the policy arena argues for the development of practical estimation tools. The QALY method has emerged as a tool that is both flexible and practical. Traditional methods of estimating QALYs using self-assessed health status have been criticized for their inability to account for scale of reference and adaptation biases. Our model explicitly recognizes differences between populations with dissimilar characteristics. In fact, in the case of SE-related arthritis, we found that the assumption of population homogeneity with respect to health losses led to a lifetime QALY loss that

Diseases) is used to estimate percentages.

was 15% less than was estimated under the more accurate assumption of a heterogeneous population.

Our analysis of the use of these values for policy purposes is less encouraging. A survey of methods used to value QALYs revealed a wide range of potential values. Future research in the valuation of QALYs is needed to enhance the usefulness of estimated QALYs.

References

- Anderson, R., 2001. United States Life Tables, 1998. National Vital Statistics Reports. Centers for Disease Control and Prevention 48 (18). "
- Arrow, K., Solow, R., Portney, P., Leamer, E., Radner, R., Schuman, H., 1993. Report of the NOAA Panel on Contingent Valuation. National Oceanic and Atmospheric Administration.
- Arthritis Foundation National Office, 1999. National Arthritis Action Plan: A Public Health Strategy. Centers for Disease Control and Prevention.
- Blumenschein, K., Johannesson, M., Yokoyama, K., Freeman, P., 2000. Hypothetical versus real willingness to pay in the health care sector: results from a field experiment. *Journal of Health Economics* 20, 441-457.
- Butler, J., Burkhauser, R., Mitchell, J., Pincus, T., 1987. Measurement Error in Self-Reported Health Variables. *The Review of Economics and Statistics* 69 (4), 644-650.
- Cockburn, I., Anis, A., 1998. Hedonic Analysis of Arthritis Drugs. Working Paper 6574. National Bureau of Economic Research.
- Cutler, D., Richardson, E., 1999. Your Money and Your Life: The Value of Health and What Affects it. Working Paper 6895. National Bureau of Economic Research.
- Division of Bacterial and Mycotic Diseases, 2001. PHLIS Surveillance Data. Centers for Disease Control and Prevention, Accessed On-line, July 2001.
- Gerdtham, U., Johannesson, M., 2000. Income-related inequality in life years and quality-adjusted life-years. *Journal of Health Economics* 19, 1007-1026.
- Groot, W, 2000. Adaptation and scale of reference bias in self assessments of quality of life. *Journal of Health Economics* 19, 403-420.
- Johannesson, M., Johansson, P., 1997. Is the valuation of a QALY gained independent of age? Some Empirical Evidence. *Journal of Health Economics* 16, 589-599.
- Johnson, F., Fries, E., Banzhaf, H., 1997. Valuing Morbidity: An integration of the willingness-to-pay and health status index literatures. *Journal of Health Economics* 16, 641-665.

- Kaplan, R., Anderson, J., Ganiats, T., 1993. The Quality of Well-being Scale: Rationale for a Single Quality of Life Index. In: Walker, S., Rosser, R. (Eds), Quality of Life Assessment: Key Issues in the 1990s. Kluwar Academic Publishers, The Netherlands.
- Kuchler, F. (Compiler), 2000. Valuing the Health Benefits of Food Safety: Conference Proceedings. Economic Research Service, Environmental Protection Agency, Food and Drug Administration.
- Kuchler, F. Golan, E., 1999. Assigning Values to Life: Comparing Methods for Valuing Health Risks. Agricultural Economic Report No. 784. Economic Research Service, Department of Agriculture.
- Moore, M., Viscusi, W.K. 1988. The Quantity Adjusted Value of Life. *Economic Inquiry* 26, 369-388.
- National Center for Health Statistics, 1993. National Health Interview Survey, 1990. CD-ROM Series 10, No. 4, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1993. National Health Interview Survey, 1991. CD-ROM Series 10, No. 5, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1995. National Health Interview Survey, 1992. CD-ROM Series 10, No. 6, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1996. National Health Interview Survey, 1993. CD-ROM Series 10, No. 7, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1997. National Health Interview Survey, 1994. CD-ROM Series 10, No. 9, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1999. National Health Interview Survey, 1995. CD-ROM Series 10, No. 10, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1999. National Health Interview Survey, 1996. CD-ROM Series 10, No. 11, U.S. Department of Health and Human Services.
- National Center for Health Statistics, 1999. National Health Interview Survey Imputed Annual Family Income, 1990-96. CD-ROM Series 10, No. 9A, U.S. Department of Health and Human Services.
- Occupational Safety and Health Administration, 2000. Preliminary Economic Analysis and Initial Regulatory Flexibility Analysis for the Occupational Safety and Health Administration's Proposed Ergonomics Program Standard. U.S. Department of Labor.
- U.S. Census Bureau, 2000. Population Estimates. U.S. Department of Commerce.

Tolley, G., Kenkel, D., Fabian, R. (Eds.), 1994. *Valuing Health for Policy*. The University of Chicago Press, Chicago.

Viscusi, W.K., Evans, W., 1990. Utility Functions That Depend on Health Status: Estimates and Economic Implications. *The American Economic Review*, 80 (3), 353-374.

Zorn, D., Klontz, K., 1998. Appendix: The Value of Consumer Loss to Foodborne Reactive Arthritis", *Federal Register*, 63, May 1, 1998.

Table 1
Descriptive Statistics

| Variable | Description | Mean (Standard Error) | |
|----------------------------|--|-----------------------|----------|
| <i>Dependant Variable</i> | | | |
| Health Status | Self assessed health status (0-4) | 2.756 | (1.119) |
| <i>Arthritis Variables</i> | | | |
| Arthritis | Respondent has arthritis (d.v.) | 0.167 | (0.373) |
| Arthritis × Age | Arthritis/age interaction | 10.203 | (23.651) |
| Onset5yr | More than five years since onset | 0.105 | (0.306) |
| Age Arthritis | Average age of an arthritis sufferer | 61.10 | |
| <i>Other Conditions</i> | | | |
| | <i>Respondent has a(n): (d.v.)</i> | | |
| INTEST | Intestinal infectious disease | 0.002 | (0.041) |
| INFECT | Other infectious disease | 0.015 | (0.122) |
| CANCER | Malignant neoplasm | 0.021 | (0.144) |
| ENDBLD | Endocrine, metabolic, nutritional, or blood disease | 0.044 | (0.204) |
| MENTAL | Mental disorder | 0.019 | (0.136) |
| NERVE | Disease of the nervous system | 0.029 | (0.167) |
| EYEEAR | Eye, ear, or mastoid | 0.042 | (0.200) |
| CRD | Disease of the circulatory, respiratory, or digestive system | 0.143 | (0.350) |
| REPRO | Reproductive system disease/condition | 0.160 | (0.367) |
| MUSC | Disease of the musculoskeletal system | 0.118 | (0.323) |
| FRACSP | Fracture, dislocation, sprain, or concussion | 0.010 | (0.102) |
| OTHINJ | Other acute injury | 0.023 | (0.149) |
| OTHER | Condition not elsewhere classified | 0.044 | (0.205) |
| OVERWGHT | Respondent is overweight | 0.473 | (0.499) |
| OBESE | Respondent is obese | 0.150 | (0.357) |
| <i>Data Set</i> | | | |
| | <i>All variables d.v.</i> | | |
| 1990 | Data is from 1990 NHIS dataset | 0.159 | (0.366) |
| 1991 | Data is from 1991 NHIS dataset | 0.166 | (0.372) |
| 1992 | Data is from 1992 NHIS dataset | 0.159 | (0.366) |
| 1993 | Data is from 1993 NHIS dataset | 0.147 | (0.354) |
| 1994 | Data is from 1994 NHIS dataset | 0.154 | (0.361) |
| 1995 | Data is from 1995 NHIS dataset | 0.132 | (0.339) |
| 1996 | Data is from 1996 NHIS dataset | 0.082 | (0.275) |
| Proxy | Respondent had questions answered by other family member | 0.294 | (0.456) |

Table 1 (cont.)
Descriptive Statistics

| Variable | Description | Mean (Standard Error) | |
|---------------------------|---|---------------------------|-----------|
| <i>Regional Dummies</i> | | <i>All variables d.v.</i> | |
| Northeast | Respondent was from the Northeast | 0.206 | (0.405) |
| South | Respondent was from the South | 0.333 | (0.471) |
| Midwest | Respondent was from the Midwest | 0.241 | (0.428) |
| West | Respondent was from the West | 0.220 | (0.414) |
| <i>Education</i> | | <i>All variables d.v.</i> | |
| Some | Some education | 0.205 | (0.404) |
| High School | High school graduate | 0.389 | (0.487) |
| College | Some college | 0.399 | (0.490) |
| <i>Major Activity</i> | | <i>All variables d.v.</i> | |
| Works | Individual works | 0.611 | (0.488) |
| Housekeeper | Individual keeps house | 0.178 | (0.382) |
| In School | Individual is in school | 0.058 | (0.234) |
| <i>Other Demographics</i> | | | |
| Age | Age of individual | 44.645 | (17.643) |
| Age Squared | Age squared | 2304.45 | (1766.91) |
| Male | Individual is male (d.v.) | 0.464 | (0.499) |
| White | Individual is white (d.v.) | 0.545 | (0.498) |
| Hispanic | Individual is hispanic (d.v.) | 0.107 | (0.310) |
| Married | Individual is married (d.v.) | 0.637 | (0.481) |
| Ln(Income) | Natural log of income | 10.211 | (0.889) |
| Big City | Individual lives in a metropolitan area with more than 1 million persons (d.v.) | 0.369 | (0.482) |
| N | Number of observations | 90110 | |

Note: Dummy variables identified as d.v.

Figure 1
Arthritis Limitations by Age

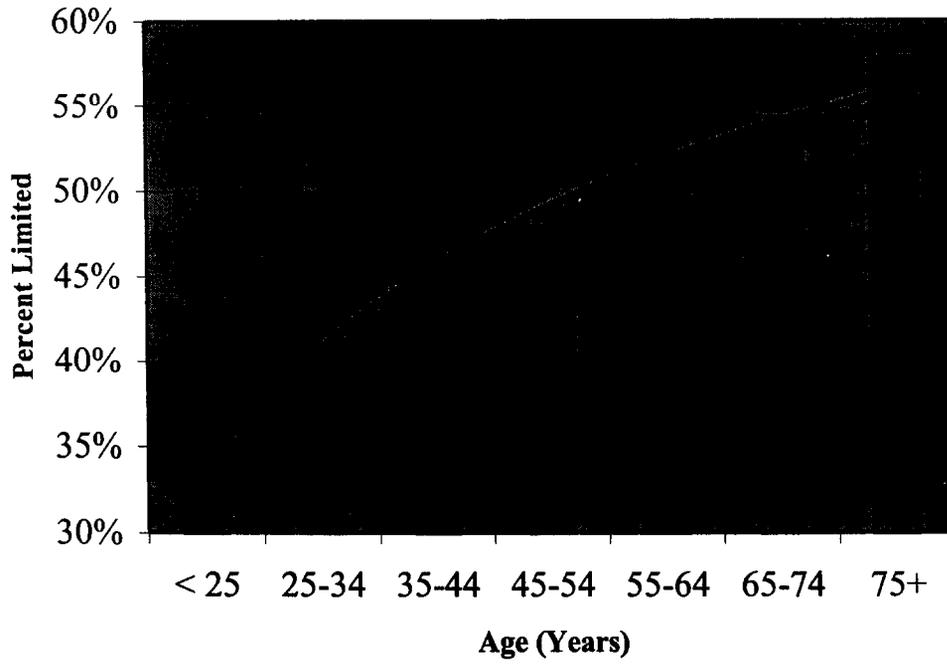


Table 2
Health Status Equations
Estimated Coefficients (Standard Errors)

| Variable | 1 | 2 | 3 | 4 |
|----------------------------|---------------------|---------------------|---------------------|---------------------|
| <i>Arthritis Variables</i> | | | | |
| Arthritis | -0.473** (0.011) | -0.339** (0.011) | -0.644** (0.040) | -0.610** (0.040) |
| Arthritis × Age | | | 0.005** (0.001) | 0.006** (0.001) |
| Onset5yr | | | | -0.095** (0.018) |
| <i>Other Conditions</i> | | | | |
| INFECT | | -0.252** (0.030) | -0.249** (0.030) | -0.249** (0.030) |
| INTEST | | -0.157* (0.087) | -0.151* (0.087) | -0.151* (0.087) |
| CANCER | | -0.491** (0.025) | -0.493** (0.025) | -0.493** (0.025) |
| ENDBLD | | -0.493** (0.018) | -0.494** (0.018) | -0.493** (0.018) |
| MENTAL | | -0.535** (0.027) | -0.533** (0.027) | -0.533** (0.027) |
| NERVE | | -0.557** (0.022) | -0.554** (0.022) | -0.555** (0.022) |
| EYEEAR | | -0.171** (0.019) | -0.173** (0.019) | -0.172** (0.019) |
| CRD | | -0.625** (0.011) | -0.626** (0.011) | -0.624** (0.011) |
| REPRO | | -0.146** (0.010) | -0.145** (0.010) | -0.145** (0.010) |
| MUSC | | -0.276** (0.012) | -0.272** (0.012) | -0.271** (0.012) |
| FRACSP | | -0.203** (0.035) | -0.203** (0.035) | -0.202** (0.035) |
| OTHINJ | | -0.341** (0.024) | -0.338** (0.024) | -0.338** (0.024) |
| OTHER | | -0.443** (0.018) | -0.440** (0.018) | -0.440** (0.018) |
| OVERWGHT | | -0.035** (0.008) | -0.036** (0.008) | -0.036** (0.008) |
| OBESE | | -0.228** (0.011) | -0.228** (0.011) | -0.227** (0.011) |

Table 2 (cont.)
Health Status Equations

| Variable | 1 | 2 | 3 | 4 |
|---------------------|----------------------|----------------------|----------------------|----------------------|
| <i>Demographics</i> | | | | |
| Age | -0.032** (0.001) | -0.027** (0.001) | -0.024** (0.001) | -0.024** (0.001) |
| Age Squared | 0.0003** (0.0000) | 0.0002** (0.0000) | 0.0002** (0.0000) | 0.0002** (0.0000) |
| Male | 0.108** (0.008) | 0.100** (0.009) | 0.101** (0.009) | 0.102** (0.009) |
| White | 0.169** (0.011) | 0.210** (0.011) | 0.211** (0.011) | 0.211** (0.011) |
| Hispanic | -0.062** (0.013) | -0.103** (0.013) | -0.104** (0.013) | -0.104** (0.013) |
| Married | -0.011 (0.009) | -0.046** (0.009) | -0.045** (0.009) | -0.045** (0.009) |
| Ln(Income) | 0.187** (0.005) | 0.172** (0.005) | 0.171** (0.005) | 0.171** (0.005) |
| Some School | 0.073* (0.044) | -0.002 (0.045) | -0.005 (0.045) | 0.004 (0.045) |
| High School | 0.310** (0.044) | 0.220** (0.045) | 0.223** (0.045) | 0.222** (0.045) |
| College | 0.530** (0.045) | 0.474** (0.045) | 0.475** (0.045) | 0.475** (0.045) |
| White Collar | 0.085** (0.009) | 0.094** (0.009) | 0.095** (0.009) | 0.095** (0.009) |
| Works | 0.536** (0.013) | 0.338** (0.013) | 0.374** (0.013) | 0.373** (0.013) |
| Housekeeper | 0.364** (0.014) | 0.261** (0.014) | 0.258** (0.014) | 0.258** (0.014) |
| In School | 0.541** (0.021) | 0.409** (0.021) | 0.409** (0.021) | 0.409** (0.021) |
| Northeast | 0.051** (0.011) | 0.019* (0.011) | 0.019* (0.011) | 0.019* (0.011) |
| South | -0.056** (0.010) | -0.072** (0.010) | -0.072** (0.010) | -0.072** (0.010) |
| Midwest | 0.041** (0.011) | 0.017 (0.011) | 0.018 (0.011) | 0.018 (0.011) |
| Big City | -0.004 (0.008) | -0.016* (0.008) | -0.017* (0.008) | -0.017* (0.008) |

| Table 2 (cont.) | | | | |
|-------------------------|---------------------|--------------------|--------------------|--------------------|
| Health Status Equations | | | | |
| Variable | 1 | 2 | 3 | 4 |
| <i>Data Set</i> | | | | |
| 1990 | 0.193** (0.018) | 0.248** (0.018) | 0.248** (0.018) | 0.250** (0.018) |
| 1991 | 0.145** (0.017) | 0.193** (0.017) | 0.194** (0.017) | 0.196** (0.017) |
| 1992 | 0.013 (0.016) | 0.034* (0.016) | 0.034* (0.016) | 0.035* (0.016) |
| 1993 | 0.012 (0.016) | 0.024 (0.016) | 0.024 (0.016) | 0.025 (0.016) |
| 1994 | 0.007 (0.016) | 0.020 (0.016) | 0.020 (0.016) | 0.020 (0.016) |
| 1995 | -0.030* (0.016) | -0.024 (0.016) | -0.024 (0.016) | -0.024 (0.016) |
| Proxy | -0.057** (0.008) | 0.096** (0.009) | 0.097** (0.009) | 0.098** (0.009) |
| <i>Cut Points</i> | | | | |
| Cut1 | -0.217 | -0.836 | -0.796 | -0.795 |
| Cut2 | 0.609 | 0.112 | 0.152 | 0.153 |
| Cut3 | 1.602 | 1.189 | 1.123 | 1.231 |
| Cut4 | 2.446 | 2.069 | 2.110 | 2.111 |
| Log Likelihood | -116,521 | -111,800 | -111,769 | -111,754 |
| <i>QALY Loss</i> | | | | |
| Age = 30 | 0.18 | 0.12 | 0.17 | 0.15 |
| Age = 40 | 0.18 | 0.12 | 0.15 | 0.13 |
| Age = 50 | 0.18 | 0.12 | 0.13 | 0.12 |
| Age = 60 | 0.18 | 0.12 | 0.11 | 0.10 |

** Two-tailed *t*-test significant at 1%

* Two-tailed *t*-test significant at 10%

Table 3
QALY Losses for Selected Subgroups

| | Age = 30 | Age = 40 | Age = 50 | Age = 60 | Age = 70 |
|----------------------|----------|----------|----------|----------|----------|
| Full Sample | 0.17 | 0.15 | 0.13 | 0.11 | 0.09 |
| Men | 0.18 | 0.15 | 0.13 | 0.11 | 0.09 |
| Women | 0.16 | 0.14 | 0.13 | 0.12 | 0.10 |
| 0-12 Years Education | 0.16 | 0.15 | 0.13 | 0.12 | 0.10 |
| 12+ Years Education | 0.18 | 0.15 | 0.13 | 0.10 | 0.08 |
| Overweight | 0.16 | 0.15 | 0.13 | 0.12 | 0.10 |
| Not Overweight | 0.17 | 0.15 | 0.13 | 0.12 | 0.10 |
| White | 0.17 | 0.15 | 0.13 | 0.11 | 0.09 |
| Non-White | 0.17 | 0.15 | 0.14 | 0.12 | 0.11 |

Table 4
Comparison of QALY Loss Estimates

| Study | Age = 30 | Age = 60 | Mean |
|-----------------------|----------|----------|------|
| This Paper | | | |
| Static | 0.12 | 0.12 | 0.12 |
| Age-Adjusted | 0.17 | 0.11 | 0.14 |
| Cutler and Richardson | 0.21 | 0.21 | 0.21 |
| Zorn and Klontz | 0.29 | 0.29 | 0.29 |

Table 5
Discounted Lifetime QALY Losses from SE-Related Arthritis

| Assumption | Life Expectancy (at average age) | Percent of All SE Cases | Discounted Lifetime QALY Losses |
|-----------------------------|-------------------------------------|----------------------------|------------------------------------|
| Homogeneity (Equation 2) | 78 | 100% | 3.17 |
| Heterogeneity (Equation 3) | | | |
| Age Group | | | |
| Under 10 | 77.4 | 39.0% | 5.14 |
| 10 to 30 | 77.7 | 21.4% | 4.17 |
| 30 to 50 | 78.8 | 19.7% | 2.86 |
| 50 to 70 | 81.5 | 11.8% | 1.58 |
| Over 70 | 86.3 | 8.0% | 0.79 |
| All Ages (weighted average) | -- | 100% | 3.71 |

Table 6
Annual Value of QALY Losses from SE-Related Arthritis

| Model | Cost Effectiveness | Adjusted VSL | Adjusted WTP |
|--|-----------------------|---------------|-------------------------|
| Value of a Life Year | \$100,000 | \$230,000 | \$1,700 to \$143,000 |
| Life Years Lost | 3.71 | 3.71 | 3.71 |
| Number of Persons Affected | 5,500 | 5,500 | 5,500 |
| Total Value of Arthritis Losses Due to SE | \$2.0 billion | \$4.7 billion | \$0.03 to \$2.9 billion |