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**The Effect of Discounting on Quality of Life Valuation Using the Time
Trade-Off**

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CHERE WORKING PAPER 2008/3

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First Version: June 2008
Current Version: June 2008

Abstract

Cost-utility analysis, combining mortality effects with health-related quality of life effects, has become the preferred method for presenting economic evaluation. It allows comparability between potential investments in different areas of health and healthcare as the outcomes are generic and designed to be applicable in multiple contexts. There are various methods for estimating health-related quality of life scores but one major approach is the use of the Time Trade-Off. Evidence has suggested that scores from this measure are relatively lower than from other measures. We argue that one possible reason for this is that the TTO method artificially deflates valuation scores because it does not take account of time preference. The extent of the deflation depends on the duration of survival offered for the health state in question, the true valuation placed on that state, and the individual's rate of time preference. This has implications for the use of TTO valuation scores in economic evaluation, particularly when models are populated using health-related quality of life scores from sources using different methods.

Background

Cost-utility analysis, which aims to compare interventions across different areas of health and healthcare, requires valuation of health outcomes, usually in the metric of quality adjusted life years (QALYs), such that the survival duration in the health state is multiplied by a preference weight that reflects the value of the health state relative to full health. Increasingly, valuations of health states are developed by use of a generic quality of life instrument (a multi-attribute utility instrument) in the population of interest, for example, patients in a randomised controlled trial. Such instruments comprise a generic health state descriptive system and a scoring algorithm, where the scoring algorithm has been developed using statistical analysis of data from a preference elicitation task in a random sample drawn from the general community.

The most widely used example of this approach is the EQ-5D, particularly the UK algorithm (Dolan, Gudex, Kind, & Williams, 1996), which is now recommended as the preferred approach to valuation of health states in the revised guidelines of the National Institute of Health and Clinical Excellence (2007). Algorithms for the EQ-5D have now been developed using the TTO method in most countries that frequently employ economic evaluation in their decision-making process (with the notable exceptions of Canada and Australia). (Norman, Cronin, Viney, King, Street, Brazier et al., 2007) The methods used in the studies has been similar, allowing comparison of scores between countries, and further establishing the precedence of the TTO based EQ-5D valuation approach. While other valuation methods are also used, particularly rating scales and standard gambles (and more recently discrete choice experiments), the TTO has become widely accepted as a standard approach for economic evaluation.

TTO was developed by Torrance et al.(1972). In TTO, health state valuations are typically derived through stated preference experiments in which individuals identify the proportion of a given survival duration they would forego to be returned to full health. While it is not mandated by any

proponents of TTO, the convention is for this period to be 10 years. The typical approach recommended is to present a hypothetical scenario of 10 years in the health state of interest and then, through a series of structured questions determine how many years of duration the respondent will forgo to be 'returned' to full health (ie the point at which the respondent is indifferent between 10 years in the health state of interest and less than 10 years in full health). Where the hypothetical health state is a stand-alone vignette, the final valuation is generally estimated as the sample mean. This approach imposes a cardinal utility function, scaled such that the value of full health is unity and the value of death is zero.

In the valuation studies, the societal valuation placed on a particular state i is assumed to be a function of the characteristics associated with that state (for example, in the EQ-5D, they use Mobility, Self-Care, Usual Activities, Pain/Discomfort and Anxiety/Depression) i.e.,

$$\text{Societal valuation of state } S_i = f(x_i) \quad (1)$$

where x_i is a vector of levels for the attributes of state i , where the attributes of interest are dimensions of quality of life described by ordered levels (typically from no problems to severe problems). Regression analysis is used to estimate the contribution of each level of each dimension to the overall score, based on the the TTO valuations given by the respondents in the sample. The form of the utility function is often assumed to be additive, although multiplicative approaches have also been advocated. (Feeny, 2006) While demographics play a role at the individual level, the convention has been to focus on societal valuations and therefore exclude individual level characteristics in the analysis, and therefore in the resulting algorithms.

The TTO works within the constraints conventionally considered to underpin the QALY model, as first formalised by Pliskin et al (1980) for preferences are defined over a chronic (constant) health state and survival. They show that for this specification of the utility function, the QALY model holds if preferences

conform to the von Neumann Morgenstern (vNM) expected utility axioms, namely that there is mutual utility independence between health states and life years, constant proportional trade-off between health status and life years and individuals are risk neutral with respect to life years. Utility independence implies that preferences defined over life years, with health state held constant do not depend on the health state. Mutual utility independence holds if this is true for both attributes (thus, if life years are held constant, utility depends only on the health state). Constant proportional trade-off between life years and health states implies that the proportion of remaining life years an individual is willing to give up for a defined improvement in quality of life is independent of the number of remaining life years. Thus, the utility associated with x years in a health state is proportional to the value of x e.g. doubling the time doubles the utility.¹

Bleichrodt et al. (1997) and Miyamoto et al. (1998) simplify these restrictions by showing that for preferences defined over constant health states over time the QALY model will hold under VNM expected utility if there is risk neutrality with respect to life years and the zero condition, which in this case requires that all health states are equally preferred when the duration of life is zero. Given that the zero condition is non-controversial in the health context, the key restriction for the QALY model under constant health states is risk neutrality with respect to life years. As noted by Bleichrodt et al. (1997) risk neutrality with respect to life years imposes a linear utility function over life years, and thus implies utility independence and constant proportional trade-off.

Empirical tests of these restrictions tend to focus either on tests of utility independence, tests of constant proportional trade-off or both. Relatively few papers directly test risk neutrality with respect to survival. The results of these tests are variable, but suggest overall that the QALY restrictions may not be

¹ There are possible exceptions to this, such as in situations where health states are good enough to be tolerated for a short period of time to complete necessary arrangements prior to death, but intolerable over a longer period. Empirical support for such exceptions is provided by Sutherland et al (Sutherland, Llewellyn-Thomas, Boyd, & Till, 1982) who evaluate preferences for a range of different health states with varying durations. Their findings suggest that, for relatively poor health states, the utility function is non-monotonic with respect to additional survival.

empirically supported. Bleichrodt et al. (1997) use modified SG and TTO tasks to test the constant proportional trade-off and utility independence restrictions of the QALY model. Their results provide support for constant proportional trade-off but not for utility independence². Bleichrodt et al. (2003) use TTO and SG experiments to test constant proportional trade-off and utility independence. Overall their findings reject constant proportional trade-off. A second experiment in the same study adds a test of utility independence of quality of life from survival duration and allows comparison of the QALY weights arising from TTO and SG tasks. The study extends Bleichrodt et al. (1997) by comparing across more survival durations, and by avoiding durations that are simple multiples of 10. Their, the results suggest loss aversion for short durations, but constant proportional trade-off is not always rejected. However the comparison across SG tasks rejects utility independence. They also find that the TTO QALY weights are greater than the SG QALY weights for short durations (which contrasts with most other comparisons of the methods), but the SG QALY weights are greater for longer durations. Spencer and Robinson (2007) have tested utility independence and argue that it generally holds.

Other studies have also rejected linearity of the utility function with respect to survival duration (as implied by constant proportional trade-off). For example, Unic et al. (1998) investigate women's preferences in relation to breast cancer treatments using a TTO task with a range of durations, and find significant differences in TTO QALY weights, suggesting a non-linear utility function with respect to duration. Similarly, the TTO QALY weights in Stiggelbout et al. (1994) in a study of testicular cancer are found to be dependent on the specified duration.

Spencer identifies potential reasons why TTO scores might differ from true valuation if we erroneously impose the QALY assumptions. (Spencer, 2003) One consideration is the issue of time preference is conventionally not considered but affects how individuals perceive the value of a future event.

² They find larger differences in the implied QALY weights across different durations in the SG task than in the TTO task.

Variability in time preference is found by Ganiats et al (2000) who use a series of binary discrete choices to examine time preferences in relation to future health outcomes across a range of disease settings, and find that across the different settings time preference ranges from a negative discount rates to a very high positive discount rate. Similarly Chapman and Coups (1999) find that a majority of respondents exhibit a zero rate of time preference in relation to poor health states (are indifferent between bad health now or in the future) and a negative rate of time preference in relation to an improving health profile. These findings not only suggest that the utility function is not linear with respect to duration (as do the studies discussed above) but also provide evidence against utility independence, because the rate of time preference appears to be dependent on the health states considered.

It is important to note that the restrictions of the QALY model are embedded in the mechanics of economic evaluation (the decision analysis framework which relies on expected utility and utility independence) and in the specific preference elicitation methods (TTO and SG) (which rely on expected utility and risk neutrality with respect to survival) used to estimate QALY based valuations of treatment outcomes. While models which relax these have been discussed in the literature (Pliskin, Shepard, & Weinstein, 1980) (Bleichrodt & Quiggin, 1999) these approaches are less tractable for evaluation. These models provide more flexible forms of QALYs (such as risk adjusted QALYs, or time non-linear QALYs), but at the cost of more complex policy evaluation in determining the value of particular health states or profiles of health states. As a result they have not been used in economic evaluation in practice.

Thus, if the TTO based QALY is to fit within the framework contained within Equation (1), it is necessary to assume that individuals are risk neutral with respect to survival. The implication of this is that they will have a zero rate of time preference (at least this is imposed in the preference elicitation task, if not in the subsequent economic evaluations). In reality, this is highly unlikely and evidence from previous studies suggests that there is only limited support to justify this assumption. The implication is that if this is not taken into

account when TTO valuations are derived, there will be systematic bias in the quality of life values given to health states other than full health. In this paper we focus on the bias introduced by TTO methods. The aims are:

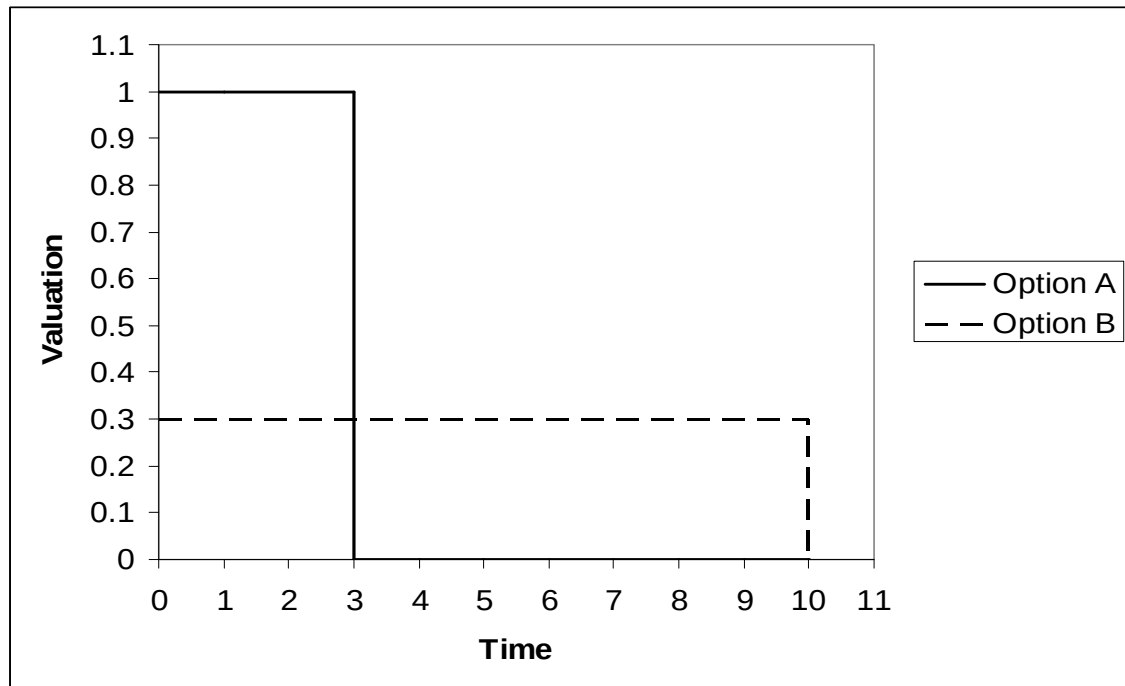
- 1) to identify the scale of deflation associated with time preference under the TTO;
- 2) to illustrate the variables which affect the scale of the deflation; and
- 3) to consider the implication for economic evaluation of using TTO scores for all utility measures, and then for using them alongside scores derived from other measures such as the Visual Analogue Scale (VAS) or Standard Gamble (SG).

Estimation of effect

States Better Than Immediate Death

For states considered preferable to immediate death, the TTO presents the respondent with a choice of 10 years (by convention) in a health state i and y years in full health. The aim of the TTO is to identify the value of y at which the individual is indifferent between the two options.

Figure 1: The Time Trade-Off



In Figure 1, the assumption is that, if the person is indifferent between Options A and B, the areas under the two lines is equal. That is:

$$U(y, FH) = U(MAX, V_i) \quad (2)$$

Where y is the period offered in full health (FH), MAX is the period offered in state i (by convention, 10 years) and V_i is the underlying valuation of the health state i . Under the QALY assumptions, this equality is achieved when

$$y = Vt \quad (3)$$

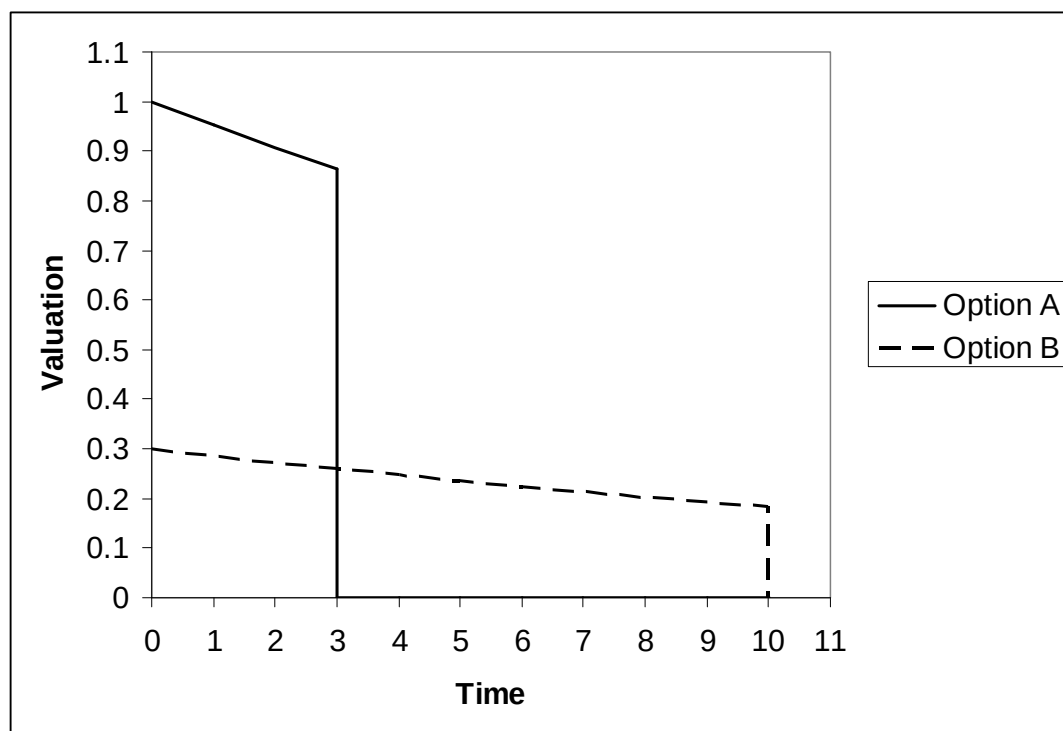
To generate S_i (converting y on to a scale bounded by 0 and 1), y is then divided by 10.

Regarding the method for summing utility across years, equation 3 is a special case in that it implicitly assumes that there is no discounting. (Sydsaeter & Hammond, 1995) The issue that needs to be considered is the

more general case under which the net present value (NPV) of the two options is likely to differ from the areas under the curves in Figure 1 since both options are subject to time preference. Additionally, since they occur over different lengths of time, the options will not be subject to a comparable proportional reduction in the net present value.

The initial approach here is to apply a fixed rate of time preference to Option A and Option B. The present value of flow of years into the future can be estimated by the sum of a geometric progression. This is true as, assuming the health state is chronic over time, the NPV of year $(x+1)$ is the product of the NPV of year x and the exponent of the discount rate.

Figure 2: Estimating the NPV in TTO



If the individual is indifferent at the point shown in Figure 2, the TTO would assign the health state in Option B a value of 0.3. However, as a result of both Options being discounted, the true valuation of the health state in Option B will differ from 0.3 (we aim to show that, to make the areas under the two curves equal, the starting point for Option B has to be higher than 0.3).

This can be illustrated in the following way: The NPV of Option A and B are the sums of geometric progressions such that

$$\text{NPV}(\text{Option A}) = \sum_{t=0}^y r^t \quad \text{NPV}(\text{Option B}) = \sum_{t=0}^{\text{MAX}} V r^t \quad (4)$$

Where r is the discount rate (for example, for a five percent discount rate, $r = 1.05^{-1}$), y is the number of years offered in full health, V is the value of the first year (0.3 in Figure 2), and MAX is the maximum period offered in either health state (conventionally 10 years in TTO).

Using the sum of a geometric progression on both t years in the less than full health state and y years in the full health state, the point of indifference occurs when

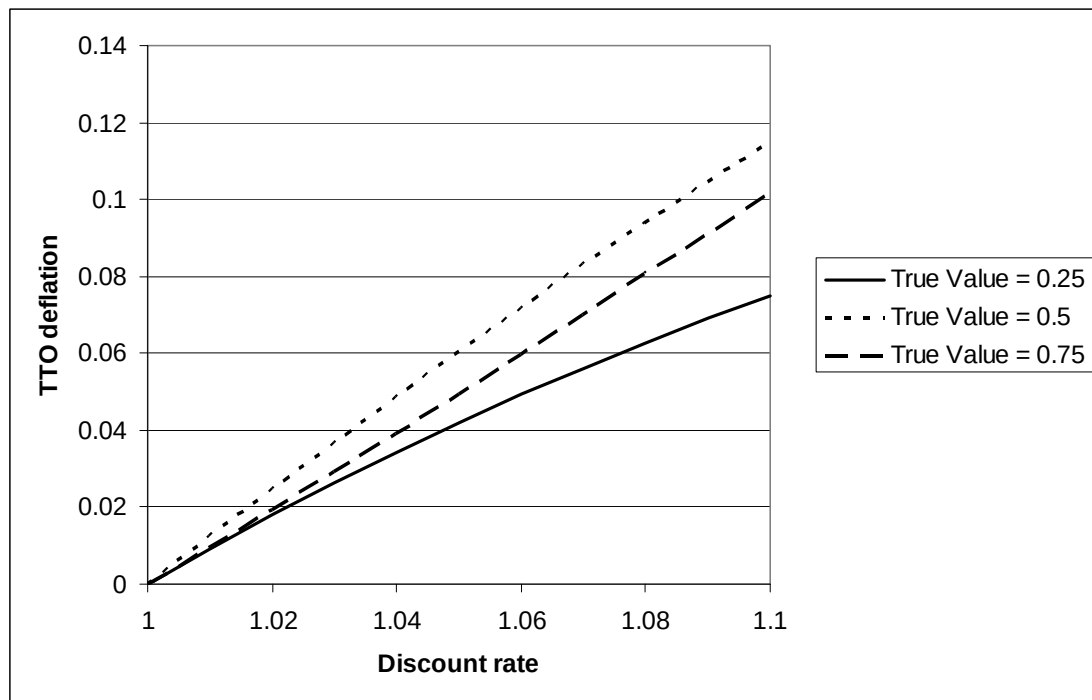
$$\frac{V(1 - r^{\text{MAX}})}{1 - r} = \frac{1 - r^y}{1 - r} \quad (5)$$

Re-arranging for y ,

$$y = \frac{\ln(1 - V(1 - r^{\text{MAX}}))}{\ln(r)} \quad (6)$$

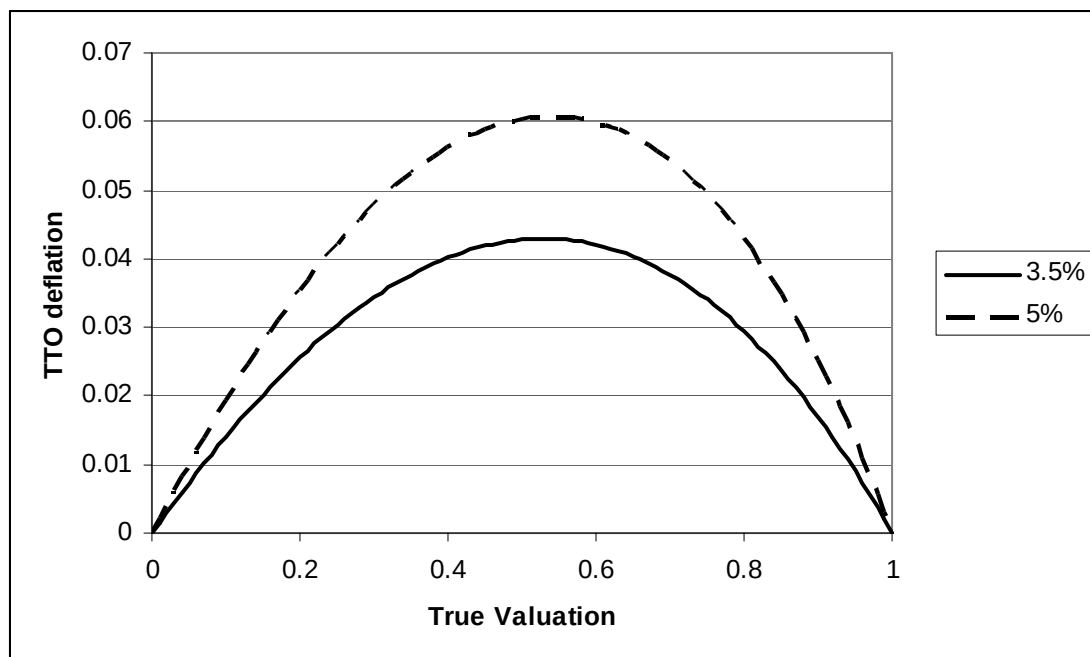
As noted previously, y is then divided by 10 to give a score between 0 and 1. The effect of discount rate on apparent value of health state i is shown for a range of underlying health values where $\text{MAX} = 10$ in Figure 3.

Figure 3: The effect of discounting and true valuation on TTO deflation



This is a significant result as it suggests the extent to which valuations derived from conventional TTO tasks are likely to underestimate true preferences once time preference is introduced. This underestimation depends on discount rate, the period offered in state i and the underlying health state valuation. If $r = 1.05^{-1}$ (i.e. a 5% discount rate), the greatest difference between underlying health state valuation and TTO score occurs when the valuation of the underlying health state is 0.54. This maximum difference is 0.0608. If $r = 1.035^{-1}$ (a 3.5% discount rate), the respective figures are 0.53 and 0.0429.

Figure 4: The effect of discounting and true valuation on TTO deflation



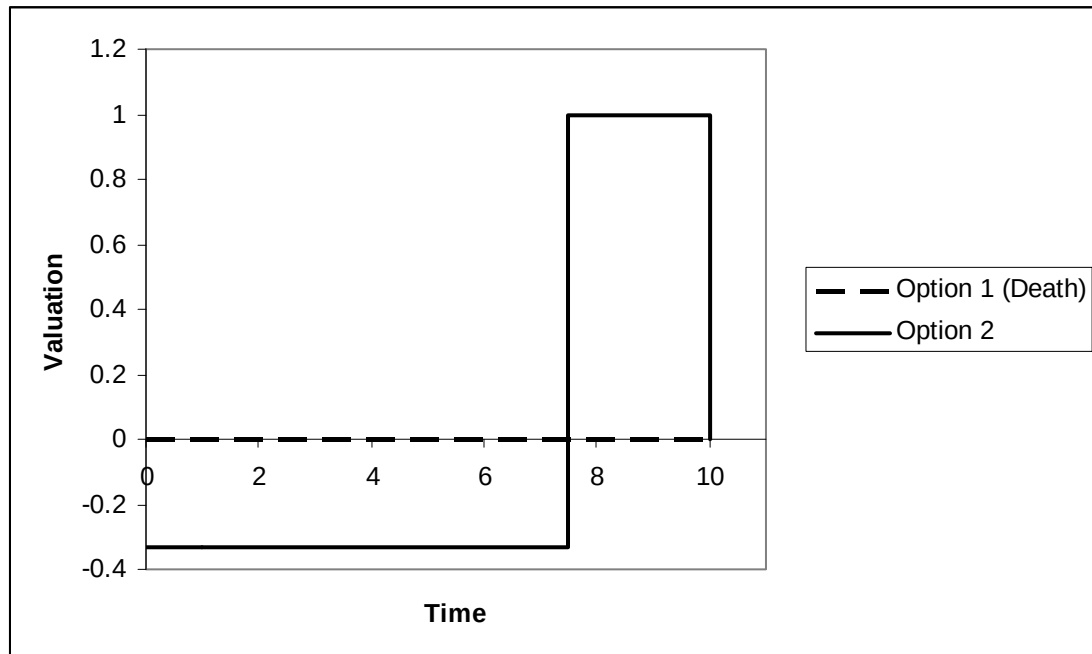
This explanation provides a contributory factor to the findings of Petrou and Hockley (2005) who find a statistically significant difference of 0.046 ($p < 0.001$) in self-reported health between TTO and standard gamble methods, and that this exists across all levels of self-reported health. Standard Gamble is not affected by time preference since the years on offer within the gamble do not differ between the options, only the chance of receiving them.

States Worse than Immediate Death

If the respondent considers a state worse than immediate death, the conventional TTO question cannot be used (as any period in full health is preferable to 10 years in S_i). The approach most commonly used in the literature is to ask a similar question, offering immediate death or a period p in this poor health state, followed by $(10-p)$ in full health, followed by death. The point of indifference is reached as with states considered better than immediate death, and then converted on to a -1 to 0 scale, by dividing p by 10, and subtracting 1. This bounding of states between -1 and 0 is, as with bounding states better than death between 0 and 1, conventional and done to

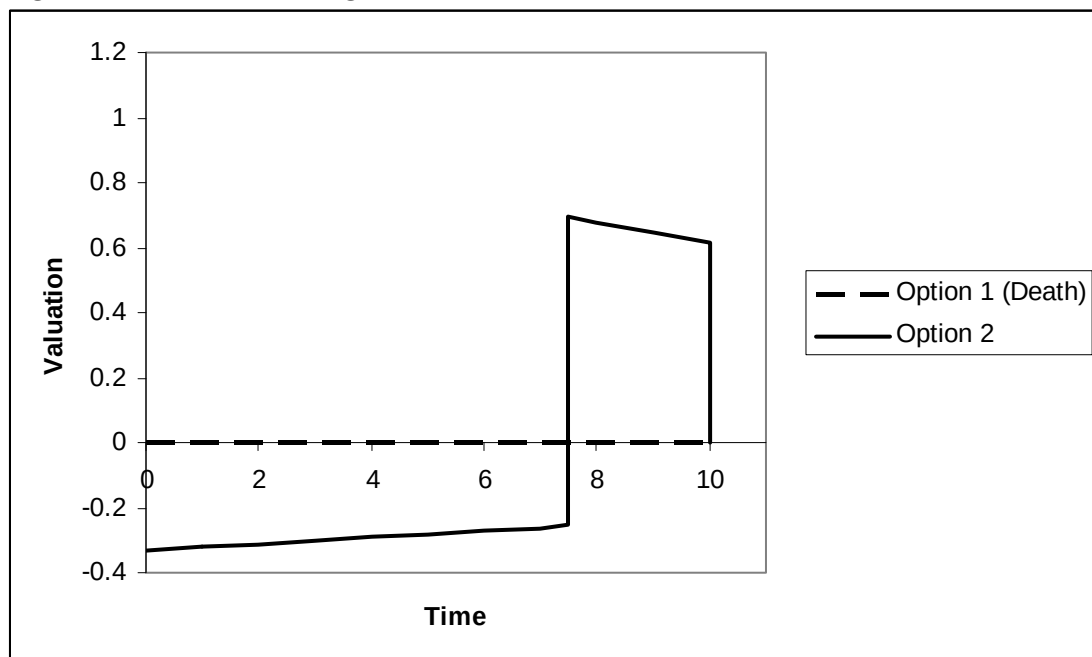
prevent the scale of the valuation of states worse than death from dwarfing those of states better than death.

Figure 5: The TTO with States Worse than Immediate Death



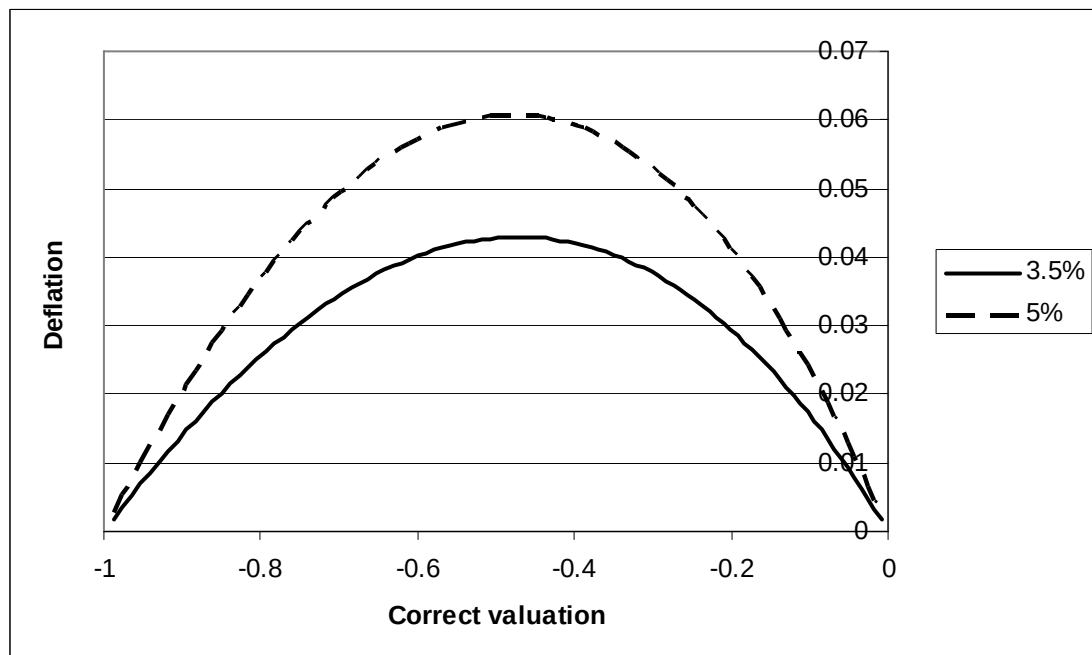
As with states better than death, this decision can be represented graphically. The period in full health (in Figure 5, the period between 7.5 and 10 years) is subject to a greater proportional decrease in value upon introduction of conventional time preference than the 7.5 years preceding it. Thus, an artificially large period in full health is required to offset the experience of poor health, reducing p , and therefore artificially deflating the health-related quality of life score.

Figure 6: Reintroducing Time Preference



As with states better than immediate death, the relationship between underlying valuation of a health state and TTO score allowing for time preference can be calculated. As before, the effect of including time preference varies according to underlying valuation of the health state and the assumed discount rate. This relationship is shown in Figure 7.

Figure 7: Deflation For States Worse than Immediate Death



In this class of states, the TTO method artificially deflates health state valuation, particularly at scores with an absolute value between 0.4 and 0.6. While the occurrence of states worse than immediate death is relatively uncommon, this result is also important when health-related quality of life is estimated using the TTO.

Discussion

The importance of this result lies in the fact that the conventional TTO method undervalues all chronic health states. Therefore, if an economic evaluation includes weights from different sources, the one outcome valued under the TTO will be unfairly discriminated against. While this is particularly important when evaluators use different sources of utility weights, it should also be considered when evaluators use solely TTO methods as the deflation of values occurs to different degrees for different health states.

One further issue with the discount rate is the assumption that individuals discount at a constant rate. This is attractive to economic evaluation as it enforces stationarity. This means that there is a constant trade-off rate

between pairs of years equally divided in terms of time (Cairns, 2001). However, there is good evidence that suggests a more hyperbolic approach is more predictive of human behaviour (Camerer, 1999). If an increasingly lower discount rate were applied as time is extended forward, the effect on TTO scores would be to artificially inflate them, as the relatively greater discounting of chronic conditions over longer periods would be less severe. This uncertainty surrounding how to precisely quantify how individuals discount future events is important as it precludes the option of adjusting TTO scores to counter the artificial deflation.

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