The role of fixed and variable time horizons in the time trade-off method

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ABSTRACT
Aim: The purpose of this study is to assess whether using different time horizons in the time trade-off method yields equivalent outcomes, and if not, whether a non-parametric correction for discounting and loss aversion can solve the disparity in outcomes.
Methods: A cross-sectional dataset was obtained through an online questionnaire. Participants underwent self-administered time trade-off utility questions for multiple health states in 10-year, 20-year and SLE time frames. The outcomes were compared using Wilcoxon signed-rank tests, bivariate correlations and multiple linear regressions.
Results: We found that time trade-off tasks using 10-year and 20-year time frames yield lower outcomes compared to the SLE time frame. This difference cannot be mitigated by correction for discounting and loss aversion, but the predictive power increases when the correction is applied.
Conclusions: The 10-year and 20-year time frames yield valid results with no significant difference between the outcomes. Outcomes obtained using the SLE time frame appear to need a downward correction. We conclude that the use of 10-year and 20-year time frames is adequate for the time trade-off method.
KEYWORDS: Time trade-off, time horizon, health utility measurement

1. Introduction

Across the world welfare increases steadily as income rises and the poor are lifted out of abject poverty. Conjointly with rising income comes the demand for better healthcare, as more expensive care becomes gradually more affordable to a wider audience and attitudes towards welfare policies change (Blekesaune, 2007). Affluent countries have long struggled with the increased demand for health and healthcare, in part because cutting back on welfare policies seems difficult (Kenworthy, 2009). Paired with the innovative drive for better healthcare this creates increasingly expensive health technology, driving up the healthcare budget. In order to keep healthcare affordable while maintaining or improving efficiency, reliable methods are needed to assess the cost-effectiveness of health technology. This allows governments and other organizations to allocate scarce resources in such a way that societal welfare can be maximized. One important input in cost-effectiveness analyses is the gain that health technology produces, which can be expressed in quality-adjusted life-years, a function of life duration and quality of life.

Time trade-off (TTO) valuations are used to assess the quality of life in specific health states, which are described in the generalized EuroQol classification system. In TTO valuation tasks respondents are asked the amount of life-years they are willing to give up to be indifferent between a specified non-optimal health state and perfect health. To make this comparable the time horizon (time frame in which the valuation is fitted) used often in the literature is a 10-year fixed time horizon (Arnesen et al., 2005).

Biases in the utility estimation using TTO may result in the dismissal of cost-effective medicines and medical procedures, or approval of inefficient health technology. With the ongoing rise of healthcare demand and expenditures across the globe, reducing biases in TTO can have a considerable positive impact on the delivery and expenditures of healthcare, especially given the increasing awareness that resource allocation must be addressed in a systematic rather than intuitive manner (Eichler et al., 2004). Several countries introduced guidelines or legislation to mandate cost-effectiveness assessment of at least some aspects of health care, most often for the reimbursement of pharmaceuticals (Towse et al., 2002, pp. 56-68).

A recent resurgence of interest in a bias found in TTO valuations is the impact of subjective life expectancy (SLE) on TTO outcomes. Henceforth, SLE will be referred to as the remaining amount of life-years a respondent expects to live.

Heintz et al. (2013) find that SLE has an impact on age- and sex-based actuarial life expectancy TTO valuations in patients. One cause for this relation between SLE and TTO is assumed to be the (unobserved) reference point created by SLE. For example, someone who expects to live for another sixty years will already regard a 10-year time horizon as a loss and thus is willing to give up less additional years. Whereas someone who expects to live only five years will give up more using the same 10-year time horizon, because the first five years to be given up are regarded as a gain. The authors speculate this may be caused by the difficulty to detach from the patients' own health state and SLE. Several studies find the same effect of SLE on TTO in the general population, although less pronounced (Van Nooten & Brouwer 2004; Van Nooten et al. 2009). Van Nooten et al. (2014) find that SLE and the implemented time horizon are important to consider when using TTO valuations. However, it is not clear whether in a direct comparison a TTO task using an SLE time horizon yields different results than one with a 10-year time horizon. Also unclear is whether this implied difference between SLE and 10-year TTO tasks can be explained through discounting (impatience and diminishing marginal utility of life-years) and loss aversion (the trade-off being treated as a gain or loss based on the reference point, with loss looming larger than gains), or if other factors are at play. The source and possible bias correction mechanism for the impact of SLE on 10-year TTO is an important venue of research. Hence, this study will compare the outcomes of a 10-year TTO valuation task with an SLE TTO task using a within subject approach. Additionally, the 20-year time horizon is included in this study, since it is a commonplace alternative and allows for a more meaningful comparison between the time horizons.

The research question used to investigate the relation between time horizons will be:

What is the difference in time trade-off outcomes when using a 10-year duration compared to a subjective life expectancy time horizon?

The hypothesis used to answer this question is:

The difference in outcomes using a 10-year duration and subjective life expectancy can for a large part be explained by loss aversion and discounting. Based on existing theory it is likely that a discounting and loss aversion determine most of the difference but not the entirety. For example, some illnesses are considered fine to have for 10 years but will become unbearable after 20 or more years.

The following section introduces the main concepts relevant to this study, in particular loss aversion and discounting. The next section outlines the methodology used and the particulars in transforming loss aversion and discounting into usable variables. Subsequently the results will be presented and discussed in light of previous research and the theoretical framework. The conclusion is given in the final section.

2. Theoretical framework

2.1 Time horizons in early TTO studies

The first application of the TTO method was by Torrance (1970), however, they did not use the 10-year timeframe. Instead they used fixed time horizons which were adjusted to accurately reflect time spent in specific evaluated health state conditions (e.g. 5 years for kidney disease, 4 months for tuberculosis). Likewise, other early TTO studies did not apply the 10-year time frame (e.g. Torrance et al., 1972, Mohide et al., 1988). While this is a non-random selection of the literature, the choice for a 10-year duration is a deviation from the original applications of TTO. More recently, most TTO studies apply a 10-year or 20-year fixed time frame, less often actuarial life expectancy is used, and sometimes respondents' own life expectation (Arnesen et al., 2005, Attema et al., 2013).
Among the first studies to use the now standard 10-year horizon in better than dead TTO studies was the one conducted by Dolan et al. (1996), which gives the following postulation for the use of this 10-year horizon (p. 144):

"Ten years was chosen as the time horizon because it was considered long enough for respondents to be able to make meaningful sacrifices and to be able to distinguish between states but not too long so as to be unrealistic for older respondents. It is recognised that this time horizon would have been unrealistically short for many younger respondents but it was felt that other alternatives (such as variable time horizons based on a person's own expected life expectancy) would have created even greater problems of measurement and interpretation."

2.2 Constant Proportional Time Trade-Off

The constant proportional trade-off (CPTO) of life-years for health status assumption, as defined by Pliskin et al. (1980), is said to hold if the proportion of remaining life-years that one is willing to give up for an improvement in health status from any given level to any other level does not depend on the absolute number of remaining life-years involved. That is, if an individual is willing to give up four life-years in a 20-year time frame to go from health state X to full health (FH), he should also be willing to give up the same proportion to go from health state X to FH in a 10-year time frame, which is equivalent to two life-years.
The applied time frame does not influence the interpretation of TTO outcomes if the CPTO assumption holds, since it allows for direct comparison through extrapolation. However, Attema et al. (2010) find that violations to the CPTO assumption are common and, therefore, that health state valuations depend on durations, even after correcting for utility of life duration curvature. They also find that in a conventional TTO with a 'short' duration, loss aversion (i.e. increased sensitivity to losses) may relate especially to the amount of time left to live and consequently is stronger for smaller time horizons (durations), making respondents overly reluctant to trade off life-years, which

leads to overestimation of TTO values. For ‘long’ durations, the absolute amount of life-years sacrificed may become dominant, making people reluctant to trade off more than some absolute amount of time. Thus, the absolute amount of time remaining is most influential for shorter TTO durations and the absolute amount of time sacrificed is most influential for longer durations. The result will be that individuals give up fewer years for short and long durations, and will be less driven by these considerations in between these two points, causing TTO values to be an U-shaped (i.e. parabolic) function of duration.

Another factor of consideration with CPTO is the proportional heuristic, where, in a TTO question for (Y, Q), the respondent blindly chooses X as a proportion of Y for health state Q. The proportional heuristic might push people to trade off life-years proportionally, even when it is not expected, such as for preference reversals (Stalmeier et al., 1996).

2.3 Loss aversion

Respondents should be willing to give up more years to get out of more severe health states. However, they will not trade off beyond certain points, as described in the previous section. A likely cause for this phenomenon is the aversion of loss which is broadly supported by empirical evidence. Loss aversion is defined as people being more sensitive to losses than to gains when viewed from a particular reference point, as defined by the Prospect Theory (e.g. Bleichrodt, 2002, Kahneman and Tversky, 1979). This reference dependence we find in Prospect Theory states that the status quo at the time of the valuation is the point of reference from which gains and losses are determined, and from where losses are weighted heavier than gains.

Van Nooten et al. (2009) show that respondents for whom SLE exceeds the time horizon are less willing to trade off any years of life in a 10-year TTO, the amount of years traded off is also affected. They attribute this to the probable explanation that respondents felt ‘cheated’ out of life-years. The more years they got ‘cheated’ out of, the fewer years people were willing to sacrifice additionally. Dolan et al. (1996) suggested that respondents who do not believe they will live for 10 more years might willingly give up the ‘excess’ life-years, thereby depressing the apparent value attached to the evaluated health states. When using SLE TTO there is no depression or inflation of the apparent value attached to health states caused by ‘excess’ or ‘lacking’ life-years, since the time horizon is lined up with SLE.

Robinson et al. (1997) use the Prospect Theory to explain why a health state has to be below some tolerance level before respondents are willing to give up any time to avoid it. Because of the weighted difference between gains and losses, a gain in quality of life has to be disproportionally large compared to the loss of expected life duration, thus creating respondent inertia. This effect is mainly an issue when assessing mild health states, where the apparent utility is close to the threshold of tolerability. When the time horizon increases, such as, on average, with SLE compared to 10-year fixed, the diminishing marginal returns of life-years and constant proportionality may decrease the gap in quality of life increase needed to surpass the threshold of tolerability, meaning willingness to trade off any life-years increases in the time horizon. Thus, we surmise that both SLE and 20-year fixed time frames may be preferable over a 10-year fixed time frame when eliciting TTO values for mild health states, because it reduces respondent inertia if SLE is, on average, larger than 10 years. This implies that the larger the time frame the smaller the threshold of tolerability effect, therefore larger time frames yield lower and more consistent elicited utility values for mild health states.

2.4 Subjective Life Expectancy

If values are systematically dependent on the used time horizon, this begs the question which frame will generate values that best reflect preferences in a consistent manner. Some studies suggest that SLE may be a more appropriate time frame in TTO than a fixed time horizon, since respondents would evaluate from their reference point (Van Nooten and Brouwer, 2004; Van Nooten et al., 2009, 2014; Heintz et al., 2013).

More formally, assume an individual's preference structure can be represented by:

$$U(x) = \begin{cases} u(x) if\ x\ \geq SLE \\ \lambda u(x) if\ x\ < SLE \end{cases} \qquad (2.1)$$

where $\lambda > 1$ is a loss aversion index, which governs the exchange rate between gain and loss utility units, and *u* is the utility amount of life-years *x*. A fixed time frame TTO task involves a gain in quality of life relative to the reference case, and an extension of a loss in longevity if SLE is higher than the fixed time frame (or a reduction in a gain if SLE is lower than the fixed time frame).

Whereas a SLE time frame eliminates the impact of reference dependence, other complications, relative to 10-year fixed, loom as the time horizon increases in length, which may have to be subjected to correction in order to acquire valid outcomes. Namely, the diminishing marginal returns of life-years and the maximum endurable time (MET) of severe health states. Following the description of Dolan and Stalmeier (2003), MET is a time beyond which people do not wish to live. In other words, after a certain threshold is reached the value of severe health states can become negative, that is, worse than death.

Since both diminishing marginal returns of life-years and MET reduce the elicited utility values relative to 10-year fixed, we surmise that using corrected TTO values which address these issues mitigates the problem, in this paper a version of corrected TTO will be used addressing discounting and loss aversion. When comparing traditional 10-year fixed TTO values with corrected SLE TTO values the residue can then be explained by MET, and other (unknown) factors. However, there is no robust way of testing the composition of the residue, since a considerable part of the variation of respondent valuations will remain unaccounted for (Dolan & Roberts, 2002).

To diminish the effects of the threshold of tolerability, diminishing marginal return of life-years, and MET, while keeping the values comparable across multiple studies, a valid approach may be to use a 20-year fixed time frame, as it comes closer to the flat of the U-shaped utility of life duration curve where the absolute amount of time remaining and absolute amount of time sacrificed as described by Attema et al. (2010) have a relatively small influence.

Several studies have looked into the effect of subjective life expectancy of the respondents on 10-year TTO outcomes. They find suggestive evidence of the impact of SLE on 10-year TTO outcomes (e.g. Heintz et al., 2013, Kattan et al., 2001, Van Nooten et al., 2009). Subjective life expectancy has also been applied as a time horizon in literature (e.g. Brown et al., 2002, Sharma et al., 2002, Shah et al., 2004, Real et al., 2008). In these studies the subjective life expectancy is elicited using a neutral frame and consequently applied by using the obtained number of years as the time frame. This approach can be argued as making the trade-off more meaningful since it aligns with their expected endowment. However, when applying SLE as the time horizon in TTO studies two crucial concerns arise: comparability driven by constant proportional trade-offs and dealing with biases due to gains and losses.

2.5 Discounting

Dolan and Jones-Lee (1997) show that the effect of discounting is non-trivial and omission can lead to significant underestimation of elicited utility values, as more discounting leads to an increased willingness to trade off life-years. The magnitude of this underestimation depends in part upon the severity of the health state impairment.

In order to account for the effect of discounting on the elicited TTO values this study will use a general non-parametric discounting model that measures discounting at the individual level. To obtain individual discount rates, the respondents will be asked to answer a small number of direct indifference questions following the Direct Method described by Attema et al. (2012).

2.6 Known factors influencing TTO outcomes

Van Nooten et al. (2015) show that next to SLE, age, and sex, the variables living together [with a life partner] and having children are also influential. The influence of these factors may have been attributed to the variable being married in other studies. Respondents with children indicated more often they had a specific point in time in mind they would like to reach, for example seeing their (grand)children grow up or being at their wedding. Of those without children, many of the reasons revolved around having a family. Quality of life at older ages may therefore be less relevant in a TTO using a 10-year time frame, because relevant ages normally are not reached within the 10-year time frame. The implication of this finding is that older people are trading off differently. They are less likely to trade off (additional) life-years, creating an upward bias in utility. If we do not control for the underlying factors for these deviations we won't mitigate the time inconsistency related to the utility derived from 'big moments that could be', which are subject to considerable uncertainty, both on possibility of occurrence and on obtained utility at the point of consumption.

3. Research Methods

3.1 Data collection

Data for this research was obtained through spreading an online Qualtrics survey aimed at the general public in the Netherlands. The survey was conducted in Dutch.

In order to obtain the necessary data to answer the research question and hypothesis several variables had to be elicited.

To make a comparison between a fixed time horizon and one based on subjective life expectancy, the SLE has to be elicited. This was done using a direct question stating: "how old do you expect to become?" The variable was then converted by subtracting age for further use in the questionnaire, creating a remaining SLE variable.

For the comparison between the different time horizons nine TTO tasks were presented to the respondents in a pseudo-random order. All possible orders were evenly distributed among respondents, meaning that all possible orders are approximately evenly used, so that we may assume that order effects are negligible because it is mitigated sufficiently. The TTO tasks are comprised of three health state evaluations (a mild, moderate, and severe health state), each elicited in three different time horizons (a SLE, 10-year, and 20-year fixed timeframe). A description of the defined health states can be found in appendix A.

To be able to explain a difference between outcomes using different time frames, we also elicited loss aversion and discounting using direct indifference questions in which two options must be matched.

The health status at the time of the response was also elicited scaled from 0 to 100, which was elicited using a Visual Analogue Scale (VAS), and thus likely suffers from an end-aversion bias (see Torrance et al., 2001). This likelihood is strengthened by the elicited EQ-5D-5L values, which for most people do not explain why their current health is well below 100, as they are in perfect health according to EQ-5D-5L. The income variable describes the net monthly income of individuals.

3.2 Corrected time trade-off: conceptual approach

The approach we took requires that the utility of subjectively expected remaining lifetime (for convenience, SLE) is specified at 0. Consequently, we have to fix the utility of this maximum outcome in the elicitation method. In doing so we make use of an unconventional approach, as we only consider negative utilities for the utility of life duration function, which is not intuitive but makes sense as we only study the loss domain. However, negative utilities are only used for analytical purposes, so the respondent is unaware of it and thus unaffected by it. Furthermore, it does not hamper computation of adjusted TTO values since utility will still be increasing in duration. Still, this change of notation requires modifying the utility computations. In the conventional approach the adjusted TTO value would be computed as $L(X)/L(SLE)$. With $L(SLE) = 0$ this is of course not possible, the following remedy is used. First of all, we can freely set the lower bound at $L(0) = -1$.

We then have to equate the changes in utilities as seen from the reference point (i.e. the SLE) and the current health state. The full health (FH) option of the TTO will be a gain in health during X years, and a loss in lifetime spent in the current health. The respondent is indifferent between them if these are equal:

$$\{U(FH) - U(H)\} * \{L(X) - L(0)\} = \{L(SLE) - L(X)\} * U(H) \tag{3.1}$$

As usual, we fix $U(FH) = 1$ (and implicitly we already set $U(Dead) = 0$). We then obtain:

$$\{1 - U(H)\} * (L(X) + 1\} = -L(X) * U(H) \leftrightarrow \frac{1-U(H)}{U(H)} = -\frac{L(X)}{L(X)+1} \leftrightarrow U(H) = L(X) + 1 \tag{3.2}$$

If there is loss aversion, we add a loss aversion parameter to this equation:

$$\{U(FH) - U(H)\} * \{L(X) - L(0)\} = \lambda * \{L(SLE) - L(X)\} * U(H) \tag{3.3}$$

which can be rewritten as:

$$U(H) = \frac{L(X)+1}{(1-\lambda)*L(X)+1} \tag{3.4}$$

The function $L(X)$ that we use for corrected TTO is the discounted value of X using the linear interpolation from the elicited discounting periods. This equation is used to compute the corrected TTO values, it can also be used to compute traditional TTO values by taking $\lambda = 1$ and $L(X) = \frac{X}{T} - 1$ which gives the usual formula for a TTO value, which is:

$$U(H) = X/T \tag{3.5}$$

where T denotes the time horizon that was used (i.e. 10-year, 20-year or SLE) and $U(H)$ is the annual utility of health state H. The value of X is obtained through direct elicitation using the respective health state TTO tasks for 10-year, 20-year and SLE time frames.
In order to compute $L(X)$ and λ we also obtained discounting and loss aversion values through a direct matching procedure. The discounting elicitation process is a slight adaptation from the Direct Method by Attema et al. (2012) since they use a direct choice procedure, for computational purposes the Direct Method is applied fully.
The discounting levels were elicited by splitting up the SLE in four quarters by first eliciting the halfway point $d^{-1/2}$. Since we set the upper and lower bound as 0 and -1 respectively, the discounting values are also in the loss domain for analytical reasons.

The question posed to the respondents is:
"For which value of X are you indifferent between option A and B?", where option A is equal to living in perfect health for X years followed by the mild health state for $SLE - X$ years, and option B is equal to living in the mild health state for X years followed by perfect health for $SLE - X$ years. The respondent is indifferent when the following equation holds:

$$DU(d^{-\frac{1}{2}} - d^{-1}) = DU(d^0 - d^{-\frac{1}{2}}) \tag{3.6}$$

where $d^{-1} = 0$, $d^0 = SLE$ and $d^{-1/2}$ is the halfway point where the period before and after have the same discounted utility. In a similar manner $d^{-1/4}$ and $d^{-3/4}$ are elicited, splitting up the halves in two equivalent parts so that we now have four equivalent time periods. The question is thus equivalent to the elicitation question for $d^{-1/2}$ with the exception that the upper and lower bound are now defined by $d^{-1/2}$ and either d^{-1} or d^{0}. This can be described in the following equations:

$$DU(d^{-\frac{1}{4}} - d^{-\frac{1}{2}}) = DU(d^{0} - d^{-\frac{1}{4}}) \tag{3.7}$$

$$DU(d^{-\frac{3}{4}} - d^{-1}) = DU(d^{-\frac{1}{2}} - d^{-\frac{3}{4}}) \tag{3.8}$$

where $d^{-1} = 0$, $d^{0} = SLE$, $d^{-1/2}$ is the halfway point, and $d^{-\frac{1}{4}}$ and $d^{-\frac{3}{4}}$ delineate the quarters with the halfway point and the maximum and minimum respectively.
Furthermore, to estimate the discounted utilities which fall in-between several interpolations could be used, but we will use the most straightforward one which is linear interpolation.

3.3 Loss aversion elicitation
The loss aversion parameter λ is elicited in three prospects, using the direct matching adaptation from the direct choice method described by Abdellaoui et al. (2016). First, a mixed prospect is presented to the respondent to assess risk aversion. After, both a loss and a gain prospect are posed in a certainty equivalence question. The three prospects can be described using the equations described below. In this study the variable that is 'shifted' is directly elicited (i.e. in an open matching question).
For the mixed prospect the respondent can choose between living until SLE or taking a gamble which gives longer life expectancy G with probability 0.5 or a shorter duration $\mathcal{L}$ with probability 0.5.
In this study G is fixed at $SLE + 10$ years, in this prospect the certain equivalent is fixed at SLE and the loss is shifted until indifference is reached. Given that $L(SLE) = 0$ this can be evaluated by:

$$w^{+}(0.5)L(G) + w^{-}(0.5)L(\mathcal{L}) = 0 \tag{3.9}$$

where $w^{+}(0.5)$ and $w^{-}(0.5)$ are the weighting functions for a probability of 0.5 to acquire a gain or a loss, respectively.
The second prospect is a choice between a certain gain of x_1 years and a gamble giving either a gain G or no gain (i.e. the SLE), both with probability 0.5. The certain equivalent is shifted until indifference is reached. Again, given that $L(SLE) = 0$ this gives:

$$L(x_1^{+}) = w^{+}(0.5)L(G) \tag{3.10}$$

The last prospect is a choice between a certain loss of x_1 years and a gamble giving either a loss $\mathcal{L}$ or no loss (i.e. the SLE), both with probability 0.5. $\mathcal{L}$ is fixed at the value elicited in the first prospect. The certain equivalent is shifted until indifference is reached. This gives:

$$L(x_1^{-}) = w^{-}(0.5)L(\mathcal{L}) \tag{3.11}$$

Combining the elicited prospects 3.9, 3.10 and 3.11 it is straightforward to show that:

$$L(x_1^{+}) = -L(x_1^{-}) \tag{3.12}$$

Loss aversion will be defined as the slope of the utility function for loss relative to that for gains. This can be described in the following equation:

$$\lambda = \frac{L(x_1^{-})/x_1^{-}}{L(x_1^{+})/x_1^{+}} \tag{3.13}$$

Hence, from combining equations 3.12 and 3.13 it follows that:

$$\lambda = \frac{x_1^+}{-x_1^-} \tag{3.14}$$

3.4 Data transformations

Since direct elicitation was used (i.e. open matching questions) people were allowed to equal the shifted variables to the SLE. The elicited values for x_1 relative to the SLE thus could be 0, which creates a division by zero issue in the loss prospect. To deal with these missing variables the loss aversion for people with this issue was approximated. Because in this case we deal with $\lambda \to \infty$ we want to ascribe as large a value as possible, however, since a disproportionally large value skews the analyses by a lot we equalized the missing values with the largest elicited loss aversion values among all respondents.

We excluded all TTO task responses in which people equaled the imperfect health state to death since this is an influential anomaly which given the health states is extremely unlikely. Seven respondents were excluded because of this reason and one datapoint in the severe health state was set to missing, so it will be excluded from the analyses.

3.5 Analyses

In general the decision-making process regarding compensation of procedures and medicines is made at the aggregate level, since it is mostly taken by national governments and international organizations which deal with large populations so that individual variations are mostly a non-factor in the decision-making process. Given this assumption of aggregate level decision-making we may also assume that decision-makers, at least to some extent, make use of the mean and median utilities of involved health states as decision factors. Therefore we will analyze whether there is or is not a significant difference between the time frames used in the means of the elicited utility values. To compare the relevant characteristics between time frames we make use of Wilcoxon signed-rank tests to address the non-parametric nature of the data. We also look at the differences using correlation analyses to assess predictive power of traditional and corrected utilities, and thus how corrected values compare to traditional values.

To control for other factors which may significantly impact the valuation of health states differently across time frames and health states we perform a regression of known-factor variables, as described in chapter 2.6 as well as a measure of other control variables.

4. Results

4.1 Descriptive statistics

Table 1 is divided in a set of sub-tables which collectively describe the data set we obtained through the online survey, which allows us to make an assessment of relevant sample characteristics. Table 1A describes the continuous variables, most importantly the age and remaining SLE.

Table 1A. *Descriptive statistics*

	Mean	Std. Dev.	Min	1st Qrt	Median	3rd Qrt	Max
Age	31.23	14.30	12	22	25	33	68
SLE	53.53	17.18	7	47	59	64	86
Health	82.29	14.56	20	75	88	93	100
Length	176.87	8.95	158	170	176	183	200
Weight	72.78	13.40	44	62	72	80	117
BMI	23.16	3.78	17	21	22	26	35
Income	1542.50	1078.25	0	500	1700	2500	3600
Observations	75						

The sample describes a broad set of the age continuum, however, most of the sample falls within a relatively small age gap between 22 and 33 years of age. Paramount to all other descriptive statistics is the remaining SLE mean of 53.53. The variable time horizon is based on the SLE and will be compared to fixed 10-year and 20-year time horizons, since the SLE mean is 53.53 we can conclude that there will be a significant difference between the fixed and variable time horizons, with the variable time duration being much longer than the fixed durations, thus obtaining meaningful results which aren't convoluted by ambiguity because on average they stay wide from the fixed time horizons.

Table 1B shows the educational attainment of participants by frequency and percentage of the sample size. The sample size consists for 66.67% of highly educated respondents, which is well above the national Dutch average. Likely consequences are that the comprehension of the questions and the consistency of the answers are (slightly) better than people with a lower educational attainment, ceteris paribus. Descriptive statistics for employment status are not tabulated, however, 94.67% of the respondents is employed either full time (32%), part time (24%) or as a student (38.67%), with the remaining 5.33% being retired or unemployed.

Table 1B. *Educational attainment*

Educational Attainment	Frequency	Percentage
Primary education	2	2.67
Preparatory vocational secondary education	4	5.33
Senior general secondary education	10	13.33
University preparatory education	9	12.00
Higher vocational education	18	24.00
Bachelor's degree	11	14.67
Master's degree	21	28.00
Observations	75	

4.2 Paired difference analysis

Table 2 presents the elicited and corrected TTO utilities by time frame and health state. In general, shorter time frames seem to produce lower mean utilities with higher standard deviations. Worse health states produce lower utilities, as expected, but also higher standard deviations. The likely cause for this is the impact of non-traders, as the gap between traders and non-traders gets progressively larger with more debilitating health states. However, this explanation does only partially deal with the different standard deviations between traditional and corrected SLE utilities. This suggests that the correction mechanism pulls the observations further apart.

Table 2. *Mean utilities*

	Mild	Moderate	Severe
TTO 10	0.886 (0.155)	0.809 (0.185)	0.646 (0.205)
cTTO 10	0.839 (0.218)	0.756 (0.250)	0.579 (0.304)
TTO 20	0.893 (0.133)	0.825 (0.173)	0.647 (0.205)
cTTO 20	0.833 (0.187)	0.717 (0.268)	0.564 (0.279)
TTO SLE	0.921 (0.114)	0.888 (0.128)	0.708 (0.217)
cTTO SLE	0.887 (0.187)	0.854 (0.176)	0.667 (0.275)

Standard deviation is denoted in parentheses.

These results are particularly interesting as the direction of the deviation from SLE utilities relative to 10-year and 20-year utilities is slightly unexpected. We expected that SLE utilities would be lower than utilities in fixed time frames, since the amount of remaining life-years is considerably larger than in a 10-year or 20-year time frame (as the average SLE is 53.5) even when giving up significantly more life-years. It may be that the effect is explained by the unwillingness to give up more life-years than a certain fixed amount. However, this explanation is unlikely since the difference is also present in the mild and moderate health state, in which the amount of life-years given up is lower than that absolute amount. Unless the maximum amount they are willing to give up is based on health state severity. Table 3 shows that the difference between the fixed time frames compared to the SLE time frame is statistically significant.

Due to the non-parametric nature of the results we performed Wilcoxon signed-rank tests to determine whether there is a significant difference between the traditional utilities derived using the three time horizons. This comparison was made across all assessed health states and can be found in table 3, with the sub-tables corresponding to the mild, moderate, and severe health states. We consider traditional pairs and corrected pairs the most important outcomes, hence all following results reflect only on those and not on the pairings between corrected and traditional values. Since we perform multiple tests on the same dependent variable we consider a Bonferroni correction appropriate. As the same dependent variable is used five times in all cases ($k = 5$) the p-values have to be below $\alpha_{corrected} = \alpha/k$ to be significant. The corrected p-values are $p = 0.01$ and $p = 0.002$ for the significance level of 5% and 1% respectively.

We found that both the traditional and corrected 10-year and 20-year time frames were not significantly different across all health states. However, the SLE time frame was significantly different from both the traditional and corrected 10-year and 20-year time frames across all health states. When performing a Bonferroni correction the following differences become insignificant compared with the uncorrected significance level: traditional 20-year and SLE durations in the mild health state; corrected 10-year and SLE durations in the mild health state; traditional 10-year and SLE durations in the severe health state.

When we do consider mixed pairs we find that the corrected SLE utilities are not significantly different from the 10-year and 20-year time frames across all health states. It is promising that we can correct the variable SLE time horizons to fit with uncorrected fixed 10-year and 20-year durations, since it allows us to compare elicited SLE TTO utilities with fixed time horizons, thus allowing a more direct comparison between studies with distinct time horizons.

Table 3A. *Paired difference of mild health state utilities (p-values)*

Mild health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.5466	1				
TTO SLE	0.0048	0.0145	1			
cTTO 10	0.0772	0.0793	0.0097	1		
cTTO 20	0.0693	0.0463	0.0004	0.2535	1	
cTTO SLE	0.9767	0.9028	0.1270	0.0206	0.0073	1

H_0: No significant difference

Table 3B. *Paired difference of moderate health state utilities (p-values)*

Moderate health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.7958	1				
TTO SLE	0.0000	0.0001	1			
cTTO 10	0.0427	0.0188	0.0000	1		
cTTO 20	0.0087	0.0020	0.0000	0.1032	1	
cTTO SLE	0.0668	0.1875	0.0640	0.0001	0.0000	1

H_0: No significant difference

Table 3C. *Paired difference of severe health state utilities (p-values)*

Severe health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.6580	1				
TTO SLE	0.0185	0.0017	1			
cTTO 10	0.0219	0.0202	0.0026	1		
cTTO 20	0.0118	0.0056	0.0001	0.6560	1	
cTTO SLE	0.4687	0.4116	0.1557	0.0007	0.0000	1

H_0: No significant difference

4.3 Bivariate correlation analysis

To get a better sense of the validity of these corrections we performed correlation analyses across the three health states. The results of these analyses are presented in bivariate correlation matrices in table 4, with the sub-tables corresponding to the mild, moderate, and severe health states. We found significant correlations between both traditional and corrected TTO utilities within their health state. All bivariate correlations are significant at a 1% significance level. All paired traditional and all paired corrected utilities are significant at a 0.1% significance level. This means that after Bonferroni correction all correlations are still significant. The common trend across health states is that the fixed time frames show the strongest correlation amongst themselves.

The corrected utilities show higher correlation coefficients across all health states, again disregarding the mixed cases. This evidence suggests that we cannot reject the hypothesis, even though the paired difference analysis conveys a different message. We find that the difference in outcomes using a 10-year duration and subjective life expectancy can be corrected partially by correcting for loss aversion and discounting, since the bivariate correlations get uniformly stronger across all health states. However, the significant difference in utilities persists after correcting for loss aversion and discounting. The most likely explanation for this is that CPTO does not hold, which may be caused by the utility of a health state being dependent upon the duration.

Table 4A. *Correlation matrix of mild health state utilities*

Mild health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.744**	1				
TTO SLE	0.472**	0.533**	1			
cTTO 10	0.718**	0.592**	0.510**	1		
cTTO 20	0.482**	0.701**	0.492**	0.788**	1	
cTTO SLE	0.387**	0.427**	0.815**	0.704**	0.658**	1

* $p < 0.01$ ** $p < 0.001$

Table 4B. *Correlation matrix of moderate health state utilities*

Moderate health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.764**	1				
TTO SLE	0.566**	0.549**	1			
cTTO 10	0.668**	0.506**	0.401**	1		
cTTO 20	0.360*	0.534**	0.328*	0.680**	1	
cTTO SLE	0.354*	0.323*	0.676**	0.667**	0.649**	1

* $p < 0.01$ ** $p < 0.001$

Table 4C. *Correlation matrix of severe health state utilities*

Severe health state	TTO 10	TTO 20	TTO SLE	cTTO 10	cTTO 20	cTTO SLE
TTO 10	1					
TTO 20	0.759**	1				
TTO SLE	0.580**	0.632**	1			
cTTO 10	0.680**	0.477**	0.343*	1		
cTTO 20	0.454**	0.463**	0.312*	0.844**	1	
cTTO SLE	0.425**	0.382**	0.669**	0.739**	0.757**	1

* $p < 0.01$ ** $p < 0.001$

4.4 Multiple linear regression analysis

We investigate whether individual characteristics are factors that affect the outcomes in TTO valuation tasks to find whether the results found so far hold without additional corrections. In particular, the composition of the population and sample may have an impact on outcomes if other factors play a role. As discussed in chapter 2.6, some variables are known factors of impact which will be included in this analysis. These include all of the following variables: remaining subjective life expectancy, age, sex, having children, and living together with a life partner. The variable age will be dropped since it is likely strongly correlated with remaining SLE, which might otherwise introduce multicollinearity. A separate model will include these variables and a score of other control variables. Included as control variables are whether the respondents live in a city with more than 50,000 inhabitants, their health at the day of the response (elicited using a Visual Analogue Scale), whether they expect their health state to change within 10 years, their Body Mass Index, and whether they drink five or more alcoholic consumptions in a week. Educational attainment was not included, since the sample is mostly concentrated in high education levels, which may make the relatively small lower education levels prone to fluke results. Once again, we separated the analyses by health state. The main point of interest in these regressions is to look for a significant contrast in the effects between different time horizons and to a lesser extent health states. The results are shown in table 5 for fixed time horizons and table 6 for the variable time horizon, with the sub-tables corresponding to the known-factor models and control models respectively. No significant results were found with the exception for sex in the moderate 20-year model which is significant at 5%. These differences disappear when we add control variables. Since we find no significant contrasts we can conclude that this sample does not need correction for other factors, whether this applies in general cannot be concluded, especially given previous evidence on the impact of the known factors.
Correction for sex is not deemed necessary since our sample is evenly distributed between males and females.

Table 5A. *Known-factor fixed time horizon models*

	(1) Mild 10	(2) Moderate 10	(3) Severe 10	(4) Mild 20	(5) Moderate 20	(6) Severe 20
Remaining SLE	0.0015	0.0006	-0.0004	0.0008	-0.0008	-0.0024
Male	-0.0560*	-0.0778*	-0.0030	-0.0408	-0.0871**	-0.0451
Cohabitate	0.0260	0.0509	0.0180	0.0265	-0.0195	0.0290
Child	0.0558	0.0305	0.0477	0.0192	0.0287	-0.0387
Constant	0.8101***	0.7902***	0.6496***	0.8556***	0.9127***	0.8011***
R^2	0.0706	0.0810	0.0277	0.0439	0.0737	0.0432

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5B. *Control fixed time horizon models*

	(1) Mild 10	(2) Moderate 10	(3) Severe 10	(4) Mild 20	(5) Moderate 20	(6) Severe 20
Remaining SLE	0.0007	0.0002	-0.0001	0.0003	-0.0015	-0.0023
Male	-0.0482	-0.0490	0.0074	-0.0287	-0.0703*	-0.0511
Cohabitate	0.0287	0.0560	0.0236	0.0358	-0.0046	0.0230
Child	0.0348	-0.0124	0.0402	-0.0030	0.0139	-0.0361
Urban	0.0046	-0.0235	-0.0145	0.0043	0.0489	-0.0233
Current health	0.0010	0.0012	-0.0004	0.0004	0.0006	-0.0008
Health change	-0.0152	0.0217	-0.0146	-0.0242	0.0061	-0.0021
Body Mass Index	-0.0028	0.0003	0.0050	0.0007	-0.0001	-0.0025
Alcohol	-0.0474	-0.0867	-0.0421	-0.0659	-0.0527	0.0107
Constant	0.8524***	0.7372***	0.5724	0.8534***	0.8701***	0.9397***
R^2	0.1048	0.1318	0.0419	0.0942	0.0952	0.0467

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6A. *Known-factor variable time horizon models*

	(1) Mild SLE	(2) Moderate SLE	(3) Severe SLE
Remaining SLE	0.0008	0.0007	0.0011
Male	-0.0120	-0.0379	-0.0742
Cohabitate	-0.0259	-0.0391	0.0320
Child	0.0366	0.0503	0.1085
Constant	0.8836***	0.8730***	0.6455***
R^2	0.0185	0.0412	0.0911

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6B. *Control variable time horizon models*

	(1) Mild SLE	(2) Moderate SLE	(3) Severe SLE
Remaining SLE	0.0007	0.0003	-0.0008
Male	-0.0105	-0.0369	-0.0745
Cohabitate	-0.0200	-0.0334	0.0449
Child	0.0353	0.0493	0.0927
Urban	0.0261	0.0388	0.0632
Current health	0.0012	0.0013	0.0010
Health change	-0.0332	-0.0294	-0.0189
Body Mass Index	0.0031	0.0006	-0.0061
Alcohol	-0.0139	-0.0122	-0.0544
Constant	0.7151***	0.7568***	0.7827**
R^2	0.0800	0.0919	0.1364

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusion

5.1 Main findings

We find a significant difference between utilities elicited with fixed and variable time horizons, although not in the expected direction, as the variable time horizon yielded higher outcomes compared to the fixed time horizons. The significant difference in outcomes persists after application of a non-parametric correction for loss aversion and discounting. However, we find that the correction increases the correlations between outcomes from different time horizons. So, we can conclude that the difference is explained partially by loss aversion and discounting.

Furthermore, we do not find a significant difference between time horizons by known-factor variables. We do find, however, that variance increases with more debilitating health states, but this may be explained by the impact of non-traders.

Based on these findings we do not reject the hypothesis we made. The difference in outcomes using a 10-year or 20-year duration and subjective life expectancy can partially be explained by discounting and loss aversion. In conclusion, we can say that time trade-off outcomes when using a 10-year, or 20-year, duration are lower than time trade-off outcomes when using subjective life expectancy time horizon.

5.2 Explanations

The difference between fixed and variable time horizons in the opposite direction than expected can be explained in two ways. First, it might be caused by the unwillingness to give up more than a certain amount of absolute life-years, which would have a larger impact on the variable time horizon than the fixed time horizons, since the average remaining SLE was around 53 life-years. Although a necessary assumption for this explanation is variability of the absolute life-years threshold by health state severity, since the difference is also present in the mild and moderate health state where less life-years are given up relative to the severe health state.

Second, it may be that the impact of discounting and loss aversion is smaller than we expected. An alternative to this second explanation is that the methods of elicitation used for discounting and loss aversion were not suitable. This may be caused by the alteration from direct choice to direct matching elicitation, or because a full non-parametric correction is not applicable to the problem. Respondents may especially have difficulty imagining the different outcomes in the discounting task, regardless of whether direct choice or direct matching is used. Also, when constructing an answer to the loss aversion task, people might be more rational in their answers, whereas the TTO valuation tasks are impacted differently as rationalization is more difficult in that case.

Another reason for the deviation from constant proportional trade-offs in the variable time horizon may be the diminished effect of the proportional heuristic relative to the fixed time horizons.

5.3 Possible objections

An objection against our study is that the survey we conducted was perceived to be difficult, this may be partially due to the necessity of completely constructing preferences, since a lot of people do not think about these hypothetical situations unless they are confronted with such situations in their direct surroundings. The discounting task and loss aversion in particular may have suffered from this problem. Not only are they rife with hypotheticals, they are also very abstract because of the direct matching elicitation. This makes it difficult to gauge the degree of discounting and loss aversion, which may cause an unreliable assessment of the impact of discounting and loss aversion in the difference in outcomes. Another possible shortcoming is the minor fluctuation in the elicitation procedure. The 10-year and 20-year TTO tasks were gauged using Visual Analogue Scales, which was not possible for the SLE TTO task because the software did not allow for a maximum scale value to be calculated on the fly. The VAS may incur the well-known end-aversion bias which can cause respondents to veer away from the end-point of the scale, with the possible consequence of decreasing TTO outcomes for the fixed time horizons. Since the variable time horizon didn't use the VAS, it may be the cause of the comparatively high outcomes. However, we think this is an unlikely explanation, as the difference in elicited values does not disappear in the severe health state, where the outcomes are already close to the middle and thus should be unaffected by end-aversion bias. Another minor fluctuation in the elicitation procedure is the restriction to integers in the 20-year and SLE time frames for the sake of simplicity. However, for the 10-year duration one decimal was allowed to reduce the threshold of tolerability effect and make more nuanced trade-offs possible. Since nuancing is easier for longer durations as there is a smaller difference between years relatively speaking we deemed it unnecessary for longer durations. Since there is no significant difference between the 10-year and 20-year outcomes we surmise that the results are not biased by this approach.

5.4 Other studies

Most studies on this subject suggest that higher life duration leads to lower outcomes, amongst other reasons because of lexicographic preferences (see also Pliskin et al., 1980; Miyamoto and Eraker, 1988). However, this study finds that people are less willing to trade off additional life-years when duration increases. Unlike Van Nooten et al. (2015) we only found a weak influence of having children, living together with a life partner, age, and remaining subjective life expectancy. Differences between sex were more pronounced, with males trading off more life-years compared to females. The different findings in this study may be influenced by the composition of the relatively small sample. The high educational attainment and relative youth of the sample in this study may decrease differences which would otherwise be present.

Robinson et al. (1997) argued that the threshold of tolerability might create respondent inertia. We found that respondent inertia is not present in the majority of respondents, and in some cases in which it is present this is possibly due to the attitude regarding trading off life-years for quality of life, as it may imply that people with a lower quality of life are worth less. These people did not trade off any life-years in all health states and time frames. Most other respondents did trade off life-years in all health states and time frames.

5.5 Implications

A crucial requirement for decision-making is that the results used in the decision-making process should not depend on that method used to generate the utilities. As equivalent ways to elicit health state utilities should generate equivalent results. We find suggestive evidence that this is the case for 10-year and 20-year durations. However, a downward correction has to be applied to SLE durations to generate equivalent results. Caution is required therein, as the defined health states in this study do not evidently pass the maximum endurable time threshold, so it is important to consider whether the evaluated health state has a MET. Otherwise a downward correction might be applied erroneously.

The 10-year and 20-year durations seem to be valid time frames for utility elicitation and are more consistent with each other than with the variable SLE duration. It seems wise to keep using 10-year and 20-year durations for most studies, instead of switching to using SLE as a time horizon. Since this evidence suggests that comparability between fixed time frames is better. Unless, of course, there is another good reason to prefer a variable time horizon based on SLE in a specific situation.

The method used to correct SLE durations in this study does seem to improve results, therefore further research is necessary to find whether an improved method of discounting and loss aversion elicitation may further increase the correlation, and predictive power, between TTO outcomes in different time horizons. Another important venue of research is whether there is another way to eliminate the gap in outcomes between different time horizons. Moreover, research on the time horizon with most consistent outcomes is needed, because it generates better validity in comparing different health states and thus allows better decision-making by policy makers.

Further research is also needed on the precise circumstances in which longer durations yield higher outcomes, for example, what the duration threshold is for MET to kick in for different health states.

Important for future research on this subject is a larger sample size, so that it better reflects the population and is less prone to compositional imbalances, such as the high educational attainment and young population in this study.

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Appendix A - *Description of health states*

The health states are defined within the EuroQol standard with five dimensions and five levels. The dimensions are: mobility, selfcare, usual activities, pain/discomfort, and anxiety/depression. The levels are: no, some, moderate, severe, extreme. Suffixed by problems, where appropriate extreme problems is replaced by 'unable to'.

Health state perfect

No problems walking about
No problems with performing selfcare activities (e.g. washing or dressing)
No problems with performing usual activities (e.g. work, study, housework, family or leisure activities)
No pain or discomfort
No anxiety or depression

Health state mild

No problems walking about
No problems with performing selfcare activities (e.g. washing or dressing)
Some problems with performing usual activities (e.g. work, study, housework, family or leisure activities)
Some pain or discomfort
Not anxious or depressed

Health state moderate

Some problems walking about
No problems with performing selfcare activities (e.g. washing or dressing)
Some problems with performing usual activities (e.g. work, study, housework, family or leisure activities)
Moderate pain or discomfort
No anxiety or depression

Health state severe

Moderate problems walking about
Some problems with performing selfcare activities (e.g. washing or dressing)
Moderate problems with performing usual activities (e.g. work, study, housework, family or leisure activities)
Severe pain or discomfort
No anxiety or depression