Original Research Article

MDMP&P Policy & Practice

MDM Policy & Practice
2025, Vol. 10(1) 1–12

DOI: 10.1177/23814683241305106
journals.sagepub.com/home/mpp
Sage

Implications of Diminishing Lifespan Marginal Utility for Valuing Equity in Cost-Effectiveness Analysis

R. Scott Braithwaite

Abstract

Introduction. Diminishing marginal lifespan utility (DMLU) implies that a particular lifespan increment (e.g., 1 life-year) confers lesser marginal utility if added to longer lifespans (e.g., 90 y to 91 y) than to shorter lifespans (e.g., 60 y to 61 y) if quality of life is unchanged. Because DMLU is difficult to disambiguate from discounting, risk attitude, and other elements of utility "curvature," it is poorly characterized. However, the imperative to consider equity in cost-effectiveness analysis (CEA) renders its characterization more important. **Methods.** I add certainty to the characterization of DMLU through literature review and illustrative example. The literature review synthesizes stated preference studies of utility curvature that exclude risk or probability. The example compares alternative valuations of approaches to reduce inequality in cystic fibrosis outcomes between US centers serving mostly White patients and centers serving mostly non-Black Hispanic patients, with versus without DMLU. **Results.** The existence of DMLU is likely, and empirical data support its relevance over typical CEA time horizons. The imperative to consider equity in CEA magnifies the importance of DMLU for several reasons. First, intergenerational CEAs require lower discount rates that are less likely to incidentally absorb DMLU. Second, DMLU is incompatible with the use of absolute measures of inequality aversion. Third, DMLU may bias the interpretation of relative measures of inequality aversion toward prioritarianism. Finally, not considering DMLU implicitly biases life-year–based metrics against equity. **Conclusion.** DMLU is likely to exist, can benefit from additional characterization, and may merit inclusion in CEA alongside discounting. Omitting consideration of DMLU will sometimes confer an antiequity bias and may affect the interpretation of CEAs incorporating inequality aversion.

Corresponding Author
R. Scott Braithwaite, Department of Population Health, NYU Grossman School of Medicine, 227 East 30th Street, Sixth Floor, New York, NY 10016, USA; (Scott.Braithwaite@nyulangone.org).

Highlights

- Diminishing marginal lifespan utility (DMLU) means that the value of extending lifespan may differ based on the duration of life already lived.
- DMLU is not typically considered in cost-effectiveness analyses.
- Not considering DMLU may bias cost-effectiveness analyses against equity.
- Not considering DMLU may reduce the accuracy of distributive cost-effectiveness analyses and other approaches to consider equity along with efficiency.

Keywords
cost-effectiveness analysis, QALY, utility, inequality-aversion, fairness

Date received: November 16, 2023; accepted: October 31, 2024

Cost-effectiveness analyses (CEAs) attach the same value to adding life-years to long versus short lifespans, assuming there are no age-related decrements in quality of life and that the additions occur presently rather than in the future. This brief report asks whether a third concept, diminishing marginal lifespan utility (DMLU), may also be relevant for valuing extensions of longer compared with shorter lifespans in CEA. DMLU is intertwined with the commonly cited notion of "utility curvature,"[1–5] the concavity in a utility curve that is indicative of diminishing marginal returns to scale. In the case of health, the diminishing marginal returns are to a QALY gain variably constituted from changes in lifespan and quality of life together with the probabilities and temporal proximities of these changes. However, unlike the general notion of utility curvature, the more specific notion of DMLU reflects diminishing returns to increasing lifespan only, as distinct from quality of life, probability, and temporal proximity, implying that a particular increment in lifespan (e.g., 1 additional year of life) confers lesser marginal utility if added to a longer lifespan (e.g., 90 y to 91 y) than to a shorter lifespan (e.g., 60 y to 61 y). DMLU has evident implications for valuing health equity in CEA because it implies that a life-prolonging intervention would confer greater value if allocated to a community with a 60-y life expectancy (LE) than if allocated to a community with a 90-year LE.

Department of Population Health, NYU Grossman School of Medicine, New York, NY, USA (SRB). The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author received no financial support for the research, authorship, and/or publication of this article.

Does DMLU exist?

The existence of DMLU can be inferred from the observation that people prefer to not live indefinitely long, regardless of their age, even in a hypothetical scenario in which slowing the aging process preserves health-related quality of life.[6–8] When people in resource-rich countries are surveyed about their preferred length of life, median and/or mean ages are consistent (Germany, 85 y; Norway, 91 y; United States, 90–93 y). Most people do not want to live past 100 y old (United States, 74%–91%; Finland, 67%), even if they can preserve high quality of life (United States, 56%–80%). Surprisingly, notions of ideal lifespan change little as people age. In a nationally representative telephone survey in the United States of more than 2,000 adults conducted in English and Spanish,[8] the proportion of people desiring life expectancies between 79 and 100 y of age did not change by age group (18–29 y old, 64%; 30–49 y, 70%; 50–64 y, 71%; $\geq$65 y, 70%) nor did the median preferred lifespan, ranging from 85 y to 90 y. In a regionally representative mail-based survey of community-dwelling elders in Finland, the median preferred lifespans were 91 y among people $\geq$70 y old and 96 y among people $\geq$85 y old.[6]

What Are Plausible Values for DMLU?

DMLU is difficult to measure directly because it is challenging to parse from other constituents of utility curvature.[1–5] First, because lifespan is inextricably bound to the passage of time, measurements relevant to DMLU often encompass time preference. Second, because

survival is never certain, measurements of DMLU may reflect risk attitudes unless tradeoffs are designed to be risk free, involving a known and fixed number of years to be lived (i.e., lifespan) rather than a probabilistic and average number of years to be lived (i.e., LE), or with adjustments for risk attitudes that may reflect optimism, pessimism, or other reasons for preferring a fixed lifespan to an equivalent probabilistic LE.[2] In addition, DMLU has been less often evaluated than other utility theory–based hypotheses such as correction of health utility elicitation methods to adjust for discounting and/or risk attitudes, such as probability weighting in prospect theory.[2,9]

Despite these challenges, insights about DMLU are available from studies of tradeoffs from an individual's perspective using various stated preference approaches including time tradeoffs, standard gambles, discrete choice experiments, and willingness to pay.[1,2,4,5,9–20] Table 1 shows a review of studies that parsed DMLU from other determinants of utility curvature by focusing on lifespan instead of LE (i.e., removing risk) and omitting age-related changes in quality of life. Notably, studies in Table 1 did not parse DMLU from discounting, and therefore, results reflect a combination of DMLU and discounting. However, many results have different parameterizations (e.g., power function) or have exponential declines exceeding the 3% discount rate typically used in CEAs, implying that either 1) DMLU exists apart from the effect of discounting or 2) discount rates should be substantially higher than those typically used in CEAs (Table 2).

Because the studies in Table 1 are too heterogeneous for quantitative pooling and results may reflect discounting together with DMLU, they do not yield a definitive inference for the best parameterization of DMLU. However, they inform a plausible range of DMLU parameterization choices with selected examples graphed in Figure 1, alternatively as a power function (with exponentiations ranging from 0.30 to 0.88, with 0.65 as a mid-range estimate), a declining exponential function (with exponents ranging from -0.02 to -0.25, with -0.05 as a mid-range estimate), or a logarithmic function (with 1.172 from a single estimate). For purposes of illustration, I arbitrarily parameterize DMLU with a power function of 0.65 for the remainder of this article; however, other choices based on Table 1 may be equally suitable.

Implications of DMLU for Valuing Equity

While awareness of the possibility of DMLU is not new, it can be argued that DMLU is becoming increasingly important given the imperative to value equity in CEA, for several reasons that I will explicate in the subsections that follow. First, when it is appropriate to perform CEA over time horizons sufficiently long to bridge different generations in a society, it has been argued that lower discount rates may be required. These lower rates are less likely to incidentally absorb the effects of DMLU.[25] Second, DMLU is incompatible with the use of absolute measures of inequality aversion. Third, CEAs increasingly include measures of societal inequality aversion, and DMLU may bias their interpretation by inflating the apparent level of prioritarianism.[26] Finally, DMLU creates an implicit antiequity bias in life-year–based metrics, potentially reinvigorating the question of whether to consider alternative forms for CEA metrics. While DMLU is just one component of the many forms of inequalities that ought to be considered when conducting economic evaluations, it has important implications that are not otherwise considered. These points are considered sequentially using an illustrative example (Box).

Discounting Is Unlikely to Incidentally Absorb the Effects of DMLU

It can be argued that DMLU has more academic than practical importance because the use of societal discounting already overlaps with DMLU. However, incorporating societal discount rates does not avert the need to consider DMLU. Through time horizons typical of CEAs, a societal discount rate of 3% overvalues (Figure 1) future lifespan compared with a 0.65 power function parameterization of DMLU. In addition, DMLU and discounting are conceptually distinct even though both are constructs describing the interaction of time and preferences. DMLU reflects a time-related preference that does not require envisioning various times in the future but rather requires considering only past and current circumstances (e.g., the utility of living an additional time increment, considering time already lived). On the other hand, discounting reflects a time-related preference that can be ascertained not through considering past or current circumstances but rather through envisioning various times in the future (e.g., utility of living an additional time increment at future times). Further, discounting also includes considerations beyond time preference, in particular expectations regarding future wealth, future health, and their marginal rate of substitution.[27,28] Accordingly, DMLU can theoretically be parsed from discounting empirically. For example, it may be possible to envision scenarios in which people of various ages (e.g., a 90-y-old with mild disease or a 40-y-old with severe disease) but

Table 1 Literature Review of Individual Preference Studies Quantifying Valuation of Future Lifespan with Risk-Free or Risk-Adjusted Framing[a]

Author	Year	*N*	Sample	DMLU Function	Design
Dolan and Gudex[21]	1995	39	US general population	None found	For various EQ-5D health states, respondents chose among 4 scenarios followed by death: 1) 10 y of the specified health state, 2) 1 y of the specified health state followed by 9 y of full health, 3) 9 y of full health followed by 1 y of the specified health state, 4) 1 mo of the specified health state followed by 9 y 11 mo of full health
Olsen[22]	1994	59	People with COPD attending Norwegian clinic	Exponent; median –0.066; mean –0.115	Compared TTO elicitations over 10 y and 30 y, asked to value their health state versus perfect health
Stavem et al.[23]	2002	10	MPH students University Tromso, Norway	Exponent; median –0.02; mean –0.10	Compared TTO elicitations over 5 y and 20 y for valuing "confined to wheelchair" versus perfect health
Gyrd-Hansen[24]	2002	78	Convenience sample, masters students in economics or public health, University Southern Denmark	Exponent; median –0.056; mean –0.07	Compared TTO elicitations for wheelchair-bound versus perfect health over 10 y and 30 y
Bleichrodt et al.[1]	1999	172	Erasmus University and Stockholm School of Economics	Exponent −0.035 or power 0.70	Compared 1) rank order of preference across different nonprobabilistic scenarios regarding healthy life-years followed by life-years with severe back pain with 2) rank order that would result from applying participant's standard gamble–estimated utility of severe back pain. Correlations were compared with and without various adjustments for utility curvature and prospect theory–informed probability weighting, finding best correlations
van der Pol and Roux[15]	2005	111	Aberdeen University	Exponent –0.02	Evaluated extent to which equally preferred durations of an undesirable health state (20% increase in body weight) varied when onset was delayed (45-y delay v. 15-y delay). Estimated from finding duration of worse health state (20% weight gain) starting 45 y from now worth trading off to avoid 5 y of worse health state 15 y from now
Bleichrodt et al.[3]	2005	208	Erasmus University	None found	Inferred DMLU from equally preferred distributions of QALY increases for 2 population subgroups, first, in which one subgroup receives an intermediate value (8 QALYs) and the other subgroup receives a higher value (10 QALYs); second, in which one subgroup receives a lower value (5 QALYs) and the other subgroup receives a specifiable value >10 QALYs
Abellán-Perpiñán et al.[16]	2006	1,277	Spanish population, structured sample	Power 0.65	Elicited TTOs for selected EQ-5D states and compared values over different time horizons for the tradeoff (10 y v. 1 y)

(continued)

Table 1 (continued)

Author	Year	*N*	Sample	DMLU Function	Design
Attema and Brouwer[2]	2009	70	Erasmus University	Power 0.57	Identified the interval within a time horizon such that having perfect health until and then worse health (back pain) after that interval was equally preferred to having worse health during that interval and then perfect health thereafter. The time horizon was initially 50 y, and then the experiment repeated iteratively with each identified interval becoming the new time horizon. Back-calculated from 0.75 X preference weight for 0.55 X life duration
Kvamme et al.[20]	2010	2,402	Norwegian population, structured sample	Power 0.30	Back-calculated from lesser (0.2 X) willingness to pay for same-duration life extensions delayed 10 y versus delayed 1 y, although some presented analyses (excluding delay) yielded opposite inferences
Attema et al.[4]	2012	70	Erasmus University	Exponent −0.03 to −0.09	Similar to Attema and Brouwer (2009)[2] but now with and without correction for probability weighting and risk attitude from prospect theory
Attema et al.[5]	2013	80	Erasmus University	Exponent −0.25	People asked to consider changes between 0 and 20 y from a baseline life expectancy of 30 y in full health. Changes were either additive or subtractive, and a risk-free prospect was compared with a risky prospect consisting of 2 options bracketing the risk-free prospect
Scalone et al.[17]	2015	208	Erasmus University	Logarithm 1.17	Discrete choice experiment including attributes of EQ-5D states together with variable durations (1 to 50 y) before dying
Attema et al.[18]	2015	517	Dutch population, structured sample	Power 0.88	Respondents asked to consider people of various ages (50 to 80 y old) who develop a disease for 1 y and then recover, and to evaluate prospects regarding therapy-induced changes in quality of life for that year. Controlled for inequality aversion
Lipman et al.[9]	2019	99	Rotterdam School of Management	Power 0.78	Respondents were asked to consider perfect health until age 50 y and then decrements in health for 20 y (until 70 y old), then death. Decrements were chosen corresponding to 3 EQ-5R-5L states. Utilities elicited using TTO and SG. Controlled for risk attitude, loss aversion, reference dependence, and probability weighting
Lipman et al.[19]	2022	150	Dutch population, convenience sample	None found	Same method as Attema et al. (2012)[4] but applied to various EQ-5D-5L states

COPD, chronic obstructive pulmonary disease; DMLU, diminishing marginal lifespan utility; MPH, master's of public health; QALY, quality-adjusted life-year; SG, standard gamble; TTO, time tradeoff.

[a]Most studies found evidence that future lifespan was devalued, although there was substantial heterogeneity in the magnitude of effect and the parameterizations employed.

Table 2 Tabulation of Results Graphed in Figure 2, Allocating Resources to Reduce Mortality among Cystic Fibrosis Clinics Serving Mostly White Patients versus Serving Mostly Non-Black Hispanic Patients[a]

	Without DMLU or Discounting (Life-Years)	With Discounting (Life-Years)	With DMLU (Life-Years)
Non-black Hispanic			
Before improvement	30.16	6.70	8.82
After improvement	33.89	7.58	9.63
Improvement amount	3.73	0.88	0.81
Valuation of improvement ($ US, 2023[b])	593,000	261,000	897,000
White			
Before improvement	47.60	10.80	12.32
After improvement	51.07	11.62	12.94
Improvement amount	3.47	0.82	0.63
Valuation of improvement ($ US, 2023[b])	552,000	243,000	697,000
Difference in improvement, non-Black Hispanic minus White	0.26	0.55	0.17
Valuation of difference in improvement	25,000	11,000	121,000

DMULD, diminishing marginal utility of lifespan duration.
[a]Without discounting or adjusting for diminishing marginal lifespan utility (DMLU), results are similar. With discounting but without adjusting for DMLU, benefits are noticeably larger for non-Black Hispanics than for White persons, yet the differences are still comparatively modest. However, adjusting for DMLU yields benefits that are substantially larger for non-Black Hispanics than for Whites, more reflective of the underlying health inequalities. Because discounted life-years and DMLU-adjusted life-years are sometimes far smaller than unadjusted years, comparisons between unadjusted years, discounted years, and DMULD-adjusted years are facilitated by converting them into their corresponding net monetary benefits through multiplication by their respective willingness-to-pay values ($159,000 per life-year, $303,000 per discounted life-year, and $1,110,000 per DMULD-adjusted life-year, adjusted to 2023 US$).
[b]Adjusted to 2023 $ US.

with the same LE (e.g., 5 y) and the same quality-of-life impairment (e.g., wheelchair bound) consider what portion of a 5-y lifespan they would tradeoff to live in perfect health.[2,4,19]

Extending the line of reasoning parsing DMLU from discounting, if life-years gained through a CF improvement program are not discounted and not adjusted for DMLU, their corresponding net monetary benefits would be similar for both resource investments in clinics serving largely White persons and those serving largely non-Black Hispanic persons, failing to reflect the corresponding health inequalities (Figure 2). If life-years gained are discounted and not adjusted for DMLU, benefits are noticeably larger for non-Black Hispanics than for White persons, yet the differences are still comparatively modest. However, if life-years gained are adjusted for DMLU, benefits are substantially larger for non-Black Hispanics than for Whites, more reflective of the underlying health inequalities (Figure 2).

Incompatibility with Absolute Inequality Aversion

It is important to note that DMLU is inconsistent with any absolute inequality aversion measure (e.g., the Kolm index). DMLU implies that the value of an absolute difference in lifespan duration grows smaller as lifespan increases, whereas the use of an absolute inequality index presumes that this value remains constant. For example, any absolute inequality measure would similarly value a 3.5-y increase in the LE gap between non-Black Hispanic CF LE and White CF LE, whether produced by subtracting 3.5 y from non-Black Hispanic persons or adding 3.5 y for White persons. However, these alternatives should be valued differently if DMLU exists; subtracting 3.5 y from the baseline LE for non-Black Hispanics lowers their utility by 0.70 DMLU-adjusted life-years, substantially more than the 0.58 DMLU-adjusted life-years gain in utility for Whites if 3.5 additional life-years are added.

Biased Interpretation of Relative Inequality Aversion

Inequality aversion may occur for different reasons when a valued entity is distributed unequally, including both aversion to an unequal distribution of utility from that entity (e.g., prioritarianism) and aversion to a loss in aggregate utility if that entity is both distributed unequally and has diminishing marginal returns (i.e., utilitarianism). For example, it has been often noted that the most utilitarian distribution of income is one that is

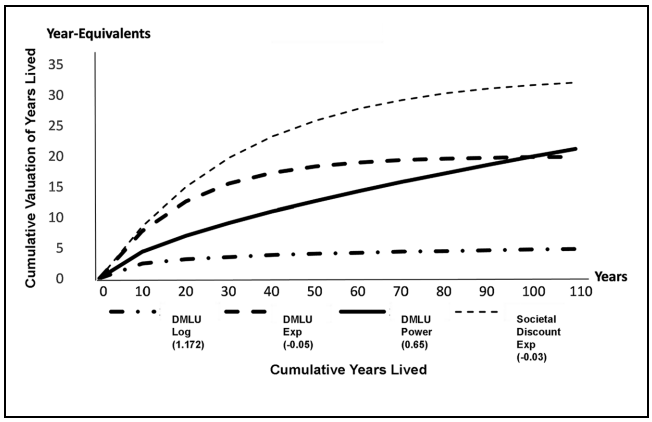

Figure 1 Relationship of alternative DMLU parameterizations to the societal discount rate of 3%. This figure graphs select DMLU parameterization functions (log, declining exponential, and power) from Table 1 (studies that quantitatively measured DMLU through tradeoffs from an individual's perspective and with risk-free framing), showing the cumulative number of years lived on the horizontal axis and the cumulative DMLU- or discount-adjusted valuation of those years on the vertical axis. These functions are compared with a societal discount rate of 3%. Parameterizations of DMLU shown here devalue cumulative years lived more than typically used societal discount rates and therefore will not be reflected by the use of discounting. DMLU, diminishing marginal lifespan utility.

equal because money exhibits diminishing marginal return.[29] For this reason, if DMLU exists, empirical elicitations of inequality-aversion of lifespan gains may reflect a utilitarian aversion to loss of aggregate lifespan-related utility as well as a prioritarian aversion to unequally distributed lifespan-related utility.

Inequality aversion can be empirically elicited by identifying the tradeoff people are willing to make to reduce inequality, even if efficiency is reduced. For example, Robson et al.[26] found that respondents would accept a loss of 1.75 life-years to reduce the lifespan gap between lower and higher socioeconomic populations quintiles from 16.0 y to 11.5 y, a result that corresponds to an inequality-aversion parameter (ε) of 10.95.

$$\prod_{i=1}^{N}\left(y_i^{\left(\frac{1}{N}\right)}\right), \varepsilon = 1$$

$$EDE_{Atkinson} = \left(\frac{1}{N}\sum_{i=1}^{N}(y_i)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}, \varepsilon \neq 1$$

Here, EDE is the equally distributed equivalent value of outcome y distributed across N measurements indexed by i, given a level of inequality aversion ε. When ε is zero, the EDE is simply the mean of the distribution. As ε increases, the EDE decreases from the mean of the distribution toward its minimum value.

However, it is unclear whether respondents making this tradeoff favored a utilitarian transfer of life-years from a group deriving lower marginal utility to a group deriving higher marginal utility, thereby increasing overall utility and/or they were averse to the unequal distribution of utility, favoring a prioritarian transfer of life-year–based utility from a group with higher baseline utility to a group with lower baseline utility. Accordingly, Robson et al.'s empirical elicitation ($\varepsilon = 10.95$) may reflect both utilitarianism and prioritarianism, rather than only one or the other. Indeed, it can be shown that the utilitarian component of the Robson tradeoff would produce an ε of 0.35, if DMLU is parameterized by a power function of 0.65.

Applying analogous thinking to the CF example, the existence of DMLU implies that adding 3.5 y to the lower LE of non-Black Hispanics would be valued more than adding 3.5 y to the higher LE of Whites. If DMLU is parameterized as a power function exponentiated to 0.65, it would be necessary to add only an additional 2.6 y to non-Black Hispanics to be valued similarly to adding 3.5 y to Whites, because both would add 0.58 DMLU-adjusted years. While these equivalent valuations correspond to an ε of 0.42 using equation (1), this ε would reflect only utilitarianism rather than prioritarianism, because it stems from a desire to raise aggregate health-related utility rather than from a desire to make the distribution of health-related utility more equal. On the other hand, levels of ε greater than 0.42 would reflect a prioritarian desire to make the distribution of health-related utility less unequal in addition to a utilitarian desire to maximize aggregate health-related utility.

For these reasons, empirically derived values of ε may not always be transportable. For example, it may be incorrect to transport Robson et al.'s empirically derived ε of 10.95 to the CF decision because the utilitarian component of ε in the Robson et al. scenario (0.35) differs from the utilitarian component of ε in the CF scenario (0.42).

DMLU Reinforces Questions about CEA Metrics That Employ Life-Years

While there is extensive literature on the suitability of life-year–based metrics for CEA, this literature has focused on QALYs rather than life-years and in particular has focused on the validity of the proportional

Box. Illustrative example: Allocating resources to improve inequities in cystic fibrosis outcomes

Illustrative example: Allocating resources to improve inequities in cystic fibrosis outcomes

Recent therapies have reduced cystic fibrosis (CF) mortality rates by approximately 2% per year, extending life expectancy from approximately 30 y in the 1990s to 45 to 50 y currently[30,31]. However, stark disparities in outcomes persist between White and non-Black Hispanic CF patients in the United States (e.g., 91.5% 18-y survival for White versus 75.9% 18-y survival for non-Black Hispanic persons).[30] For both groups, an additional 21% reduction is likely possible through improvements in care quality, standardization, and accessibility of genotype-based therapies.[31,32,33,34,35] Decision makers have a fixed budget for CF care improvement and are balancing the allocation of additional resources for centers serving mostly non-Black Hispanics versus centers serving mostly Whites. A simple population-based model (Figure 2) finds that allocating resources to reduce mortality by an additional 21% among mostly White patients with cystic fibrosis would increase their life expectancy from 47.60 y to 51.07 y, an increase of 3.47 y. Allocating resources to reduce mortality by an additional 21% among mostly non-Black Hispanic patients with CF would increase their life expectancy from 30.16 to 33.89 y, an increase of 3.73 y. When life-years are discounted at 3%, discounted life expectancy rises from 10.80 discounted years to 11.62 discounted years among mostly White patients, an increase of 0.82 discounted years, and rises from 6.70 discounted years to 7.58 discounted years among mostly non-Black Hispanic patients, an increase of 0.88 discounted years. If years are adjusted for diminishing marginal lifespan utility (DMLU) by applying a power function exponentiated to 0.65, DMLU-adjusted life expectancy rises from 12.32 DMLU-adjusted years to 12.94 DMLU-adjusted years among mostly White patients, an increase of 0.63 DMLU-adjusted years, and rises from 8.82 DMLU-adjusted years to 9.63 DMLU-adjusted years among mostly non-Black Hispanic patients, an increase of 0.81 DMLU-adjusted years. Because discounted life-years and DMLU-adjusted life-years are sometimes far smaller than unadjusted years, comparisons between unadjusted years, discounted years, and DMLU–adjusted years are facilitated by converting them into their corresponding net monetary benefits (NMB) through multiplication by their respective willingness to pay (WTP; 159,000 per life-year, $303,000 per discounted life-year, and $1,110,000 per DMLU-adjusted life-year, 2023 US dollar values), yielding NMBs of $552,000 (life-year), $243,000 (discounted life-year) and $697,000 (DMLU-adjusted life-year) for White patients and NMBs of $593,000 (life-year), $261,000, (discounted life-year) and $897,000 (DMLU-adjusted life-year) for non-Black Hispanic patients.[a]

[a]Their respective WTPs can be estimated by a benchmarked comparison that is common to all three, such as "modern medical care" versus "no modern medical care," a counterfactual that is sometimes used to infer a lower bound for WTP in the United States.[36,*] In that comparison, the incremental lifetime cost of modern medical care ($509,000 undiscounted and $135,000 discounted) was divided by its incremental life expectancy gains (4.6 y, undiscounted; 0.65 y, discounted) to yield WTP lower bounds ($159,000 per life-year and $303,000 per discounted life-year, equivalent to $1,110,000 per DMULD-adjusted life-year).

tradeoff assumption[37,38] (i.e., similar proportioned tradeoffs in life duration to avoid a utility decrement, regardless of lifespan duration). Considering DMLU broadens the discussion on the suitability of life-year–based CEA metrics beyond QALYs to encompass life-years, it may not make sense to use life-year, QALY, or any adjusted life-year metric if the time linearity implicit in these metrics is itself inconsistent with DMLU.

However, at the same time that DMLU challenges linear, life-year–based CEA metrics, it offers a way to reconceptualize them. A CEA metric incorporating DMLU could be normalized to an entire lifespan rather than to a particular number of years. I will illustrate one among many possible approaches. The distribution of life expectancies in a particular society at a particular time (T1) can be adjusted for DMLU, and then the EDE of their distribution can be calculated. This EDE of DMLU-adjusted life-years can be anchored to "1." Subsequent changes in the health of that society will affect the distribution of life expectancies, which will then affect the distribution of their DMLU-adjusted life expectancies and ultimately their EDE of DMLU-adjusted life-years. This new EDE of DMLU-adjusted life-years at a later time (T2) can be compared with the prior value to determine whether health is improved, and that comparison will consider both DMLU and inequality aversion. However, this health improvement would no longer be conveyed by an EDE-adjusted life-years–gained metric, in units of years, but rather through an EDE-adjusted lives-gained metric, in units of lives. Analogous procedures could be applied to QALYs if the proportional tradeoff assumption is accepted. Because it may be argued that an equivalent-lives metric should not be anchored arbitrarily by the LE distribution and EDE of a particular society at a particular time, a more objective anchor could be chosen, such as the greatest health in a human population that is currently foreseeable, equally distributed (for example, perfect quality of life over a lifespan of 110–115 y, the asymptotic LE when extrapolating forward historical trends in age-adjusted mortality).[39]

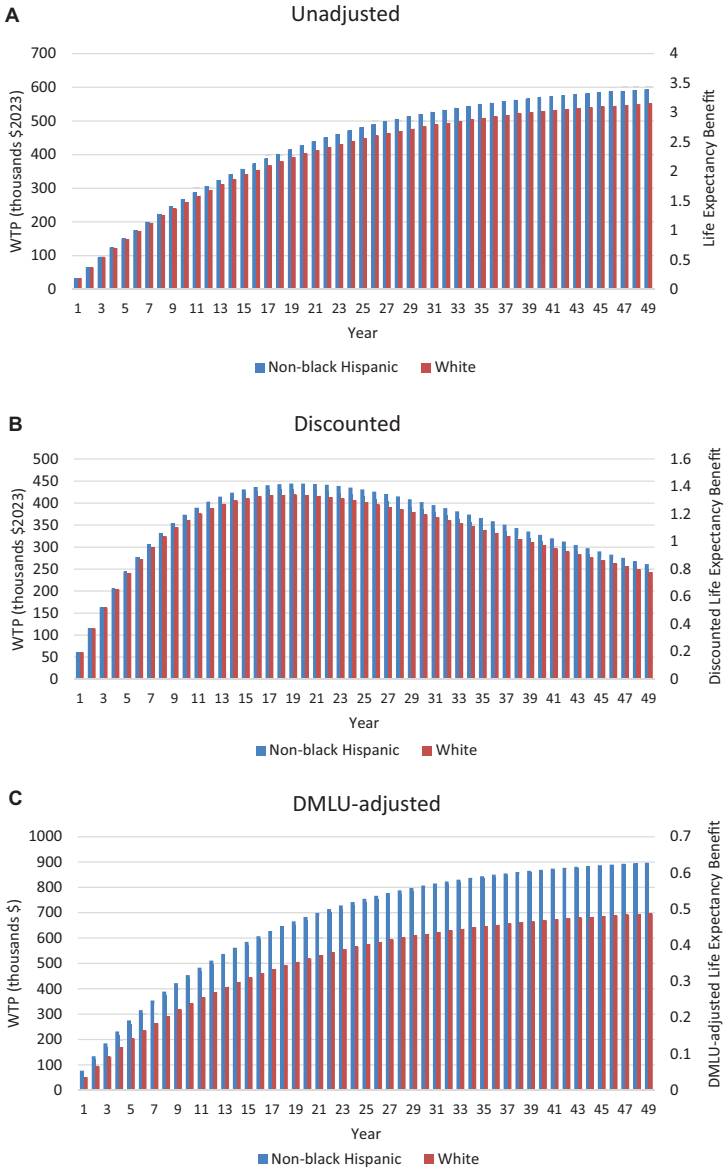

Figure 2 Results from a population-based model of survival in persons with cystic fibrosis, comparing life expectancy gain from additional resource investment in centers serving mostly non-Black Hispanic patients versus centers serving mostly White patients.

The model was developed for illustration and was made as simple as possible. The model is a 2-state state-transition model (sick, dead), programmed in Excel, and calibrated by empirically identifying mortality rate multipliers that, when applied to 2019 US lifetable estimates, produced acceptable reproduction of recent 25th, 50th, and 75th percentile survival statistics for patients with cystic fibrosis who are non-Black Hispanic (mortality multiplier empirically found to be 28.8) and White (mortality multiplier empirically found to be 9.6). Additional resource investments were assumed to reduce mortality by 21% in both groups of centers. Discounting reduced benefits by 3% every passing year, regardless of advancing age, and diminishing marginal lifetime utility (DMLU) reduced benefits by age exponentiated to the power of 0.65, regardless of advancing time. Results showed that, without any discounting or adjustment for DMLU (A), life expectancy gains increased asymptotically and were slightly greater for non-Black Hispanics than for Whites (cumulative difference in net monetary benefit [NMB], $25,000 at 50 y). With adjustment for discounting (B), gains initially increased and then decreased as the asymptotic growth slowed and was outpaced by the devaluative effect of discounting. Life expectancy gains were slightly greater for non-Black Hispanics than for Whites (cumulative difference in NMB, $11,000 at 50 y). With adjustment for DMLU parameterized to a power of 0.65 (C), gains again increased asymptotically but now were substantially greater for non-Black Hispanics than for Whites (cumulative difference in NMB, $121,000 at 50 y), more evidently reflecting the underlying inequities. Adjustment for DMLU parameterized to exponential declines would yield curves with maxima, more similar in shape to (B) than to (C).

Other Considerations

It may be argued that societal valuations of lifespan extension have already been empirically assessed, for example, by differentially assessing willingness to pay for gains in survival, gains in quality of life, or both.[20,38,40–45] According to this reasoning, because empirical assessments of lifespan extension encompass DMLU, it is unnecessary to further study or characterize DMLU. However, this reasoning omits insights that arise from identifying the unsuitability of using absolute inequality measures in distributive CEAs or from identifying the relative importance of prioritarian and utilitarian components of inequality aversion.

DMLU could further animate long-standing debates about whether QALYs are insufficiently ageist or too ageist,[46–49] as lifespan extensions for older persons would be valued less than equivalent lifespan extensions for younger persons. Relatedly, many who view QALYs as insufficiently ageist also argue that nonwelfarist approaches to health valuation (e.g., fair innings or capacity theory) may be preferable to further modifications of CEA-based metrics,[50–52] particularly since QALYs are sometimes presented as a generic measure of health divorced from the concept of utility. However, DMLU is of intrinsic importance to quantify the benefit of lifespan duration, which will always be a relevant input for CEAs. Further, scholars who are revising QALYs within a utility context, such as by incorporating descriptive insights from prospect theory, may find it useful to incorporate DMLU-adjusted lifespan.[5,9,18] Finally, it is notable that inequality aversion is being incorporated into CEA within a welfarist framework and that fair innings has recently been formulated within a prioritarian welfarist framework.[53]

Limitations

It may be argued that studies (Table 1) have not adequately parsed DMLU from individual discounting, and individual discounting may comprise the bulk of observed consequences I am attributing to DMLU. However, the implications for valuing equity in CEA would be the same because those individual discount rates would far exceed rates typically used in CEA. Accordingly, they would be incompatible with the low discount rates warranted by intergenerational CEAs, contradict the use of absolute inequality aversion measures, bias interpretation of relative inequality aversion parameters, and potentially create an implicit antiequity effect in CEAs.

This explication of DMLU has notable limitations. First, the literature review (Table 1) yielded studies that were too heterogeneous for quantitative pooling. Accordingly, it is uncertain whether and when the particular DMLU parameterization I chose (power function of 0.65) is better than others. Future studies may increase certainty regarding appropriate functional forms for DMLU parameterization. The approach outlined here does not harness rank-dependent approaches that more fully extricate DMLU from discounting, inequality aversion, and other phenomena.[3,54] Finally, the practical value of this work would be greatly facilitated by future research 1) distinguishing DMLU from discounting, 2) studying plausible DMLU parameterizations, 3) estimating how DMLU adjustment affects willingness-to-pay thresholds, and 4) consideration of incorporating DMLU into CEAs in addition to the incorporation of discounting.

Conclusion

DMLU is likely to exist and has implications for valuing equity in CEA. When inequality aversion is not included in an analysis, omitting consideration of DMLU will have an implicit antiequity effect. When inequality aversion is considered, absolute indices of inequality should be avoided. Finally, empirical estimates of inequality aversion may be biased, making societies seem more prioritarian than they really are.

Acknowledgments

Mark S. Roberts, Distinguished Professor of Health Policy and Management at the University of Pittsburgh, offered valuable insights and ideas on how to improve the revision.

Ethical Considerations

The article was not generated from human subjects research and requires no ethical review/approval.

Consent to Participate

The article was not generated from human subjects research and requires no ethical review/approval. Research participants were not part of the process, and no consent was applicable.

ORCID iD

Scott R. Braithwaite https://orcid.org/0000-0002-4095-0030

Data Availability

The scientific literature reviewed for this article is publicly available. Excel code will be made available upon request to Dr. Braithwaite.

References

1. Bleichrodt H, van Rijn J, Johannesson M. Probability weighting and utility curvature in QALY-based decision making. *J Math Psychol*. 1999;43:238–60.
2. Attema AE, Brouwer WBF. The correction of TTO-scores for utility curvature using a risk-free utility elicitation method. *J Health Econ*. 2009;28:234–43.
3. Bleichrodt H, Doctor J, Stolk E. A nonparametric elicitation of the equity-efficiency trade-off in cost-utility analysis. *J Health Econ*. 2005;24:655–78.
4. Attema AE, Bleichrodt H, Wakker PP. A direct method for measuring discounting and QALYs more easily and reliably. *Med Decis Making*. 2012;32:583–93.
5. Attema AE, Brouwer WBF, I'Haridon O. Prospect theory in the health domain: a quantitative assessment. *J Health Econ*. 2013;32:1057–65.
6. Karppinen H, Laakkonen M-L, Strandberg TE, et al. Do you want to live to be 100? Answers from older people. *Age Ageing*. 2016;45:543–9.
7. Skirbekk V, Langballe EM, Strand BH. Preferred life expectancy and the association with hypothetical adverse life scenarios among Norwegians aged 60 + . *Age Ageing*. 2021;50:2012–8.
8. Lugo L, Cooperman A, Funk C, et al. *Americans' Views on Aging, Medical Advances and Radical Life Extension*. Washington (DC): Pew Research Center; 2013.
9. Lipman SA, Brouwer WBF, Attema AE. QALYs without bias? Nonparametric correction of time trade-off and standard gamble weights based on prospect theory. *Health Econ*. 2019;28:843–54.
10. Stiggelbout AM, Kiebert GM, Kievit J, et al. Utility assessment in cancer patients: adjustment of time tradeoff scores for the utility of life years and comparison with standard gamble scores. *Med Decis Making*. 1994;14:82–90.
11. Pliskin JS, Shepard DS, Weinstein MC. Utility functions for life years and health status. *Oper Res*. 1980;28:206–24.
12. Stalmeier PF, Bezembinder TG, Unic IJ. Proportional heuristics in time tradeoff and conjoint measurement. *Med Decis Making*. 1996;16:36–44.
13. Martin AJ, Glasziou PP, Simes RJ, et al. A comparison of standard gamble, time trade-off, and adjusted time trade-off scores. *Int J Technol Assess Health Care*. 2000;16:137–47.
14. van Osch SMC, Wakker PP, van den Hout WB, et al. Correcting biases in standard gamble and time tradeoff utilities. *Med Decis Making*. 2004;24:511–7.
15. van der Pol M, Roux L. Time preference bias in time trade-off. *Eur J Health Econ*. 2005;6:107–11.
16. Abellán-Perpiñán J-M, Pinto-Prades J-L, Méndez-Martínez I, et al. Towards a better QALY model. *Health Econ*. 2006;15:665–76.
17. Scalone L, Stalmeier PFM, Milani S, et al. Values for health states with different life durations. *Eur J Health Econ*. 2015;16:917–25.
18. Attema AE, Brouwer WBF, I'Haridon O, et al. Estimating sign-dependent societal preferences for quality of life. *J Health Econ*. 2015;43:229–43.
19. Lipman SA, Attema AE, Versteegh MM. Correcting for discounting and loss aversion in composite time trade-off. *Health Econ*. 2022;31:1633–48.
20. Kvamme MK, Gyrd-Hansen D, Olsen JA, et al. Increasing marginal utility of small increases in life-expectancy? Results from a population survey. *J Health Econ*. 2010;29:541–8.
21. Dolan P, Gudex C. Time preference, duration and health state valuations. *Health Econ*. 1995;4:289–99.
22. Olsen JA. Persons vs years: two ways of eliciting implicit weights. *Health Econ*. 1994;3:39–46.
23. Stavem K, Kristiansen IS, Olsen JA. Association of time preference for health with age and disease severity. *Eur J Health Econ*. 2002;3:120–4.
24. Gyrd-Hansen D. Comparing the results of applying different methods of eliciting time preferences for health. *Eur J Health Econ*. 2002;3:10–6.
25. Braithwaite RS, Roberts MS. Are discount rates too high? Population health and intergenerational equity. *Med Decis Making*. 2021;41:245–9.
26. Robson M, Asaria M, Cookson R, et al. Eliciting the level of health inequality aversion in England. *Health Econ*. 2017;26:1328–34.
27. Ramsey FP. A mathematical theory of saving. *Econ J*. 1928;38:543–59.
28. Neumann PJ, Ganiats TG, Russell LB, et al. (eds). *Cost-Effectiveness in Health and Medicine*. New York (NY): Oxford University Press; 2016.
29. Stark O, Kobus M, Jakubek M. A concern about low relative income, and the alignment of utilitarianism with egalitarianism. *Econ Lett*. 2012;114:235–8.
30. Buu MC, Sanders LM, Mayo JA, et al. Assessing differences in mortality rates and risk factors between hispanic and non-hispanic patients with cystic fibrosis in california. *Chest*. 2016;149:380-389.
31. Rho J, Ahn C, Gao A, Sawicki GD et al. Disparities in mortality of hispanic patients with cystic fibrosis in the united states. A national and regional cohort study. *Am J Respir Crit Care Med*. 2018; 198:1055-1063.
32. Keogh RH, Szczesniak R, Taylor-Robinson D, et al. Up-to-date and projected estimates of survival for people with cystic fibrosis using baseline characteristics: A longitudinal study using UK patient registry data. *J Cyst Fibrosis*. 2018;17:218-227.
33. Palla JB. Disparities and therapeutic advances in Cystic Fibrosis. *Pediatr Pulmonol*. 2024;59:3812–3818.
34. McGarrey ME, McColley SA. Minorities are underrepresented in clinical trials of pharmaceutical agents for cystic fibrosis. *Ann Am Thorac Soc*. 2016;13:1721–1725.
35. McGarry ME, McColley SA. Cystic fibrosis patients of minority race and ethnicity less likely eligible for CFTR

modulators based on CFTR genotype. *Pediatr Pulmonol*. 2021;56:1496-1503.
36. Braithwaite RS, Meltzer DO, King JT, et al. What does the value of modern medicine say about the $50,000 per quality-adjusted life-year decision rule? *Med Care*. 2008;46:349-356
37. Miyamoto JM, Eraker SA. A multiplicative model of the utility of survival duration and health quality. *J Exp Psychol Gen*. 1988;117(1):3–20.
38. Tsuchiya A, Dolan P. The QALY model and individual preferences for health states and health profiles over time: a systematic review of the literature. *Med Decis Making*. 2005;25:460–7.
39. Dong X, Milholland B, Vijg J. Evidence for a limit to human lifespan. *Nature*. 2016;538:257–9.
40. Reckers-Droog V, van Exel J, Brouwer W. Willingness to pay for quality and length of life gains in end of life patients of different ages. *Soc Sci Med*. 2021;279:113987.
41. Pennington M, Baker R, Brouwer W, et al. Comparing WTP values of different types of QALY gain elicited from the general public. *Health Econ*. 2015;24:280–93.
42. Hall RE, Jones CI. The value of life and the rise in health spending. *Q J Econ*. 2007;122:39–72.
43. Gu Y, Lancsar E, Ghijben P, et al. Attributes and weights in health care priority setting: a systematic review of what counts and to what extent. *Soc Sci Med*. 2015;146:41–52.
44. Olsen JA. Priority preferences: 'end of life' does not matter, but total life does. *Value Health*. 2013;16:1063–6.
45. Lancsar E, Gu Y, Gyrd-Hansen D, et al. The relative value of different QALY types. *J Health Econ*. 2020;70:102303.
46. Kappel K, Sandøe P. QALYs, age and fairness. *Bioethics*. 1992;6:297–316.
47. Nord E, Street A, Richardson J, et al. The significance of age and duration of effect in social evaluation of health care. *Health Care Anal*. 1996;4:103–11.
48. Tsuchiya A. QALYs and ageism: philosophical theories and age weighting. *Health Econ*. 2000;9:57–68.
49. Harris J, Regmi S. Ageism and equality. *J Med Ethics*. 2012;38:263–6.
50. Himmler S, van Exel J, Brouwer W. Estimating the monetary value of health and capability well-being applying the well-being valuation approach. *Eur J Health Econ*. 2020;21:1235–44.
51. Mitchell PM, Roberts TE, Barton PM, et al. Assessing sufficient capability: a new approach to economic evaluation. *Soc Sci Med*. 2015;139:71–9.
52. Bleichrodt H, Quiggin J. Capabilities as menus: a non-welfarist basis for QALY evaluation. *J Health Econ*. 2013;32:128–37.
53. Adler MD, Ferranna M, Hammitt JK, et al. Fair innings? The utilitarian and prioritarian value of risk reduction over a whole lifetime. *J Health Econ*. 2021;75:102412.
54. Bleichrodt H, Diecidue E, Quiggin J. Equity weights in the allocation of health care: the rank-dependent QALY model. *J Health Econ*. 2004;23:157–71.