

Accounting for the Timing of Costs and Benefits in the Evaluation of Health Projects Relevant to LMICs

Karl Claxton

March 2018

Guidelines for Benefit-Cost Analysis Project
Working Paper No. 8

Prepared for the Benefit-Cost Analysis Reference Case Guidance Project
Funded by the Bill and Melinda Gates Foundation

Visit us on the web: <https://sites.sph.harvard.edu/bcaguidelines/>

Accounting for the timing of costs and benefits in the evaluation of health projects relevant to LMICs

Karl Claxton

I would like to acknowledge and thank the participants of the BMGF funded workshop on discounting on 14th September 2017 for their insightful presentations and discussion of topics that have informed this paper. I would also like to acknowledge and thanks the following people who kindly provided very useful comments on an earlier draft of this paper: Miqdad Asaria, Fiammetta Bozzani, Werner Brouwer, Maria Petro Brunal, Collins Chansa, Maureen Cropper, Tom Drake, Mark Freeman, Ben Groom, Markus Haacker, Julian Jamison, Mark Jit, Paul Kelleher, Margaret Kuklinski, Carol Levin, James Lomas, Jessica Ochalek, Mike Paulden, Catherine Pitt, Billy Pizer, Michelle Remme, Zia Sadique, Michael Spackman, Sedona Sweeney, Fran Sussman, Gernot Wagner and David Wilson. Any errors, omissions and misrepresentations are the responsibility of the author

Executive summary

The primary focus of this paper is to offer guidance on the analysis of time streams of multiple effects that a project may have (e.g., on health, health care costs and consumption) so that they can then be discounted appropriately. This requires a framework within which CEA and CBA can be understood and that identifies the common parameters that need to be assessed.

The common conceptual framework for CEA and BCA, which is set out in Section 2, identifies the key parameters required to express the time streams of multiple effects in a common numeraire of equivalent consumption gains and losses which can then be discounted at a social time preference rate for consumption.

Extensive reporting is recommended, as illustrated in Tables 1, 2a and 2b. Reporting the results of CEA and BCA in this way makes the assessments required explicit so the impact of alternative assumptions can be explored and analysis updated as better estimates evolve.

The quantification and conversion of the time streams of multiple effects into their equivalent health, health care cost or consumption effects avoids embedding multiple augments in discounting policies. This helps to identify where parameters are likely to differ in particular contexts, what type of evidence would be relevant, what is currently known that is relevant to low and middle income settings and how this evidence might be strengthened.

The separate and explicit accounting for these arguments provides clarity about the parameters that need to be assessed and so they can be applied consistently, while preserving the possibility of accountable deliberation about evidence, values and unquantified arguments in decision making processes.

The possible default values for the key parameters and assessments required, which are identified in Section 2 and discussed in Section 3, are summarised below.

Key parameters and assessments required		Possible estimates and default assumptions
Health opportunity costs of health care expenditure	k_{ht}	<ul style="list-style-type: none"> Estimates for most LMICs for 2015 expenditure provide initial default estimates of cost per DALY averted Initial projections of these estimates based on other published projections of health expenditure and consumption are also available These initial estimates can be refined and updated as other country specific estimates emerge, ideally using within country data where this is possible
Consumption opportunity costs of health care expenditure	k_{ct}	<ul style="list-style-type: none"> A conservative default assumption of 1 (1\$ spent on health care delivers 1\$ in net production) A conservative default assumption that the real value of the net production effects will grow at the same rate as consumption
Consumption value of health and its evolution over time	v_{ht}	<ul style="list-style-type: none"> Country specific estimate of v_h (see the recommendations from other BCA methods papers) Growth in v_{ht} can be based on growth in consumption (g_c) and two alternative scenarios of the income elasticity of demand for health A conservative scenario using an income elasticity of demand

		<p>for health of 1 (v_{ht} will grow at g_c)</p> <ul style="list-style-type: none"> Scenario using an income elasticity of demand of 2 (v_{ht} will grow at twice g_c)
Other sectors (x)	v_{xt}/k_{xt}	<ul style="list-style-type: none"> Default assumption that $v_{ht}/k_{ht} = v_{xt}/k_{xt}$ when considering impacts on other public sectors
Time preference for consumption	r_c	<ul style="list-style-type: none"> A normative assumption of zero pure time preference for social choices is not unreasonable ($\delta = 0$) Two scenarios based on alternative assumptions of inequality aversion can be used <ul style="list-style-type: none"> A conservative scenario based on $\eta = 1$ ($r_c = g_c$) Alternative scenario based on $\eta = 2$ ($r_c = 2g_c$) Other scenarios can be based on evidence of why η is likely to differ in specific contexts or different judgements about g_c
Catastrophic risk		<ul style="list-style-type: none"> It would not be unreasonable to set aside truly catastrophic risk from a common discount rate for consumption If catastrophic risk is included, it should be based on an estimate of the probability of truly catastrophic events where recovery would not be possible ($\leq 0.1\%$)
Macroeconomic risk		<ul style="list-style-type: none"> Use of r_c without adjustment for macroeconomic risk may be a reasonable default assumption for projects with shorter time horizons (<30 years) For longer time horizons or where macroeconomic risk is greater and increases more rapidly with term, declining rates may be required but should be based on uncertainty in consumption growth
Project specific risk		<ul style="list-style-type: none"> Where possible project specific risks should be included in how the time streams of consumption equivalent effects of the project are estimated A qualitative indication of whether projects are likely to be strongly pro or counter cyclical should be provided Further research is required on how the interaction of project specific and macroeconomic risk might be best quantified for the types of project relevant to LMICs

Some projects will have effects across different countries (or jurisdictions within a country) where some or all of these key parameters will differ. These parameters depend directly, or indirectly, on expected growth in consumption so they are likely to be country specific. Therefore, the net present value of a project which has effects across a number of countries will be the sum of the country specific net present values rather than the sum of effects across countries discounted at some common rate.

Contents

	Page
Executive Summary	2
1 Introduction	5
2 Conceptual framework	6
2.1 The objective of the project is to improve health	6
2.1.1 Why discount health?	6
2.1.2 Representing the effects of health care projects	7
2.1.3 Non-health impacts and non-health care costs	10
2.2 The objective of the project is to improve welfare	12
2.3 What is the distinction between CEA and BCA?	13
3 Evidence available to inform key parameters and possible default estimates	14
3.1 Health opportunity costs of health care expenditure	14
3.2 Consumption opportunity costs of health care expenditure	15
3.3 Consumption value of health and its evolution over time	16
3.4 Other constrained sectors	17
3.5 Time preference for consumption	18
3.6 Catastrophic, macroeconomic and project specific risk	19
4 Recommendations, reporting and further research	22
4.1 A summary possible default estimates	22
4.2 Reporting and aggregating effects	23
4.3 Suggestions for further research	24

1. Introduction

A decision to introduce a policy (e.g., public health, educational, environmental etc.) or provide an effective intervention (e.g., a health technology or programme of care for a particular indication) for the current population may offer some immediate health benefits but, in many circumstances, the health benefits will occur in future periods. Other projects are intended to reduce the risk of future events for the current population and others may also reduce risks for future incident patients, so the health benefits they offer will not be fully realized for many years. Future benefits are not restricted to health but may also include impacts on private consumption, reductions in future health care costs and other forms of public expenditure as well as social objectives of particular interest to the decision maker. Similarly, different policy choices and projects will not just impose health care and other costs in the current period but in future periods as well.

The question is how account should be taken of when health care and other costs are incurred and health and other benefits are received. The intention is to offer clarity about principles, the key assessment required and the evidence currently available to inform them, so that decision makers in low and middle income countries (LMICs) and other stakeholders, are better placed to judge what would be an appropriate analysis of the time streams of the multiple effects that a project may have and the discount policy to apply to them in a particular context. This includes how global bodies, which make recommendations (e.g., WHO), purchase health technologies (e.g., Global Fund) or prioritise the development of new ones (e.g., BMGF), should judge the value of projects which have effects in many different settings where appropriate discounting of costs and benefits are likely to differ.

The primary focus of this paper is to offer guidance on the appropriate analysis of time streams of multiple effects that a project may have (e.g., on health, health care costs and consumption) so that they can then be discounted appropriately. This requires framework within which cost-effectiveness analysis (CEA) and benefit–cost analysis (BCA) can be understood that identifies the common key parameters that need to be assessed. This also helps to identify where parameters are likely to differ in particular contexts, what type of evidence would be relevant, what is currently known that is relevant to low and middle income settings and how this evidence might be strengthened.

An explicit assessment of the opportunity costs associated with current constraints and the relative value of multiple effects shows that the distinction between a CEA which accounts for wider effects and a BCA, which incorporates the opportunity of cost or shadow prices of existing constraints, is more apparent than real. Both require the same assessment of the same key parameters. Reporting the results of CEA and BCA in an extensive way means that discounting procedures do not embed multiple arguments, but expose the assessment required. This also enables the impact of alternative, but plausible, scenarios to be explored and analysis to be updated as better estimates evolve. The quantification and conversion of the time streams of multiple effects into their equivalent health, health care cost or consumption effects avoids embedding multiple arguments in discounting policies. The separate and explicit accounting for these arguments provides clarity about the parameters that need to be assessed so they can be applied transparently and consistently, while preserving the possibility of accountable deliberation about evidence, values and unquantified arguments in decision making processes.

A common conceptual framework of how time streams of effects on health, health care costs and consumption is set out in Section 2. This identifies the key parameters that need to be assessed whether conducting BCA or CEA. The evidence currently available that might support their assessment in LMIC setting is discussed in Section 3 and possible default values are suggested. These recommended defaults are summarised in Section 4 before suggesting how analysis might be most usefully reported, especially when a project has effects across different contexts where parameters are likely to differ. Finally, some suggestions of priorities for further research are made.

2 Conceptual framework

A common conceptual framework within which CEA and CBA can be understood and key parameters identified is initially set out for a project which only has effects on time streams of health and health care costs. This is extended to consider effects beyond health and health care costs, where the often complex reality of multiple sectors is initially simplified into two (collective health care expenditure and private consumption) to illustrate principles. The common parameters that need to be assessed are identified and the distinction between BCA and CEA is discussed. A key implication is that discounting policies should not embed multiple arguments but the quantification and conversion of the time streams of multiple effects into their equivalent health, health care cost or consumption effects should be done explicitly before they are discounted at a rate appropriate to health, health care costs or consumption respectively.

2.1 The objective of the project is to improve health

Decision making bodies and institutions can be viewed as the agents of a principal (e.g., a socially legitimate process such as government) which allocates resources, devolves powers and gives responsibility to pursue specific, measurable and therefore narrowly defined objectives, e.g., to improve health. The values implied by the outcome of this process (e.g., government implicitly or explicitly determining collective expenditure on health care) can be regarded as a partial but revealed expression of some unknown social welfare function that may include many conflicting arguments, e.g., health equity, social solidarity among many others that are difficult to specify let alone quantify (Drummond et al 2015). In these circumstances economic analysis cannot be used to make claims about social welfare or the optimality of the resources allocated to health care. Its role is more modest, claiming to inform accountable decision-making by revealing implied values and exposing the implications of current levels of health and other public expenditure. It is this role that economic analysis has tended to play in health policy and underpins much of the evaluation of health care projects and CEAs that have been conducted (Drummond et al 2015, Coast et al 2008).¹

2.1.1 Why discount health?

In this context the reason to discount future health effects cannot appeal to the type of welfare arguments that underpin social time preference (STP) for consumption, but instead to the opportunity costs of financing health care. The health care costs of a project could have been invested elsewhere in the economy or used to reduce public borrowing at a real rate of return, which would provide more health care resources in the future and generate greater health benefits.

¹ See Drummond et al 2015 Section 2.4.3 pages 33-38

Health care transforms resources into health so from the perspective of a social planner trading health care resources over time is to trade health. Therefore, if health care costs are discounted to reflect the opportunity cost of financing health care, their health effects must also be discounted.² For example, real yields on government bonds reflect the marginal cost of increasing health care expenditure available to government (Paulden and Claxton 2012; Paulden et al. 2016). In this context the broader question of the social opportunity costs of public expenditure including the macroeconomic choice of levels and mix of taxation and borrowing (Spackman 2017) can be regarded as the responsibility of government rather than spending departments or national and supra national decision making and advisory bodies.³

2.1.2 Representing the effects projects

Estimates of the additional health care costs (Δc_h) and additional health effects (Δh) (whether measured as Quality Adjusted Life Years, QALYs, gained or Disability Adjusted Life Years Averted, DALYs) of a project or a health care intervention are commonly reported as incremental cost-effectiveness ratios (ICER).⁴ These provide a useful summary of how much additional resource is required to achieve a measured improvement in health (the additional cost per QALY gained or DALY averted). Whether the intervention will improve health outcomes overall requires a comparison with a 'threshold' (k_h) that reflects the likely health opportunity costs, i.e. the improvement in health that would have been possible if the additional resources required had, instead, been made available for other health care activities. A project will improve health overall if the additional health benefits exceed the health opportunity costs associated with the additional health care costs that must be found from existing commitments, or that require additional expenditure that could have been devoted to other health care activities ($\Delta h > \Delta c_h/k_h$).⁵

Time stream of net health effects

Most projects offer time streams of health effects (Δh_t) and health care costs (Δc_{ht}) illustrated in Table 1. The additional health care costs in each period can be reported as the health opportunity costs ($\Delta c_{ht}/k_{ht}$, in column (5) of Table 1) by applying a 'threshold' that reflects an assessment of the marginal productivity of health care expenditure relevant to that period (k_{ht}). The time streams of health benefits and health opportunity losses can then be discounted at a rate which reflects a social time preference for health (r_h).

The social choice of how much resource to devote to health care over time and the resulting health in each period reveals something about society's willingness to trade current and future health. For example, the choice of the principal in setting the level of health expenditure in each period, based on expectations about how the marginal productivity of health care expenditure is likely to evolve,

² This is commonly illustrated by a comparison of terminal and present values. The cost per QALY of a project with immediate costs and additional health benefits all occurring at a future point in time is the same whether costs are expressed at their terminal value when the health benefits occur, or discounting the health benefits back to their present value at the same rate (Nord 2011).

³ See Drummond et al 2015, page 108-112

⁴ See Drummond et al 2015, Section 2.4.1 page 27-31 and Section 4.2.1 page 79-83

⁵ This is equivalent to asking whether cost per QALY it offers is less than the cost-effectiveness 'threshold' ($\Delta c_h/\Delta h < k_h$), so long as the 'threshold' used to judge cost-effectives reflect the likely health opportunity costs.

implies values for k_{ht} . Therefore, a revealed social time preference for health⁶ can be based on the rate at which the principal can borrow or save (r_s) and whether the ‘threshold’ is expected to grow (gk_h) because this indicates the relative value (in terms of health care resources) of current compared to future health ($r_h = r_s - gk_h$) (Paulden and Claxton 2012; #Paulden et al 2017#).

Time stream of equivalent health care resources

Rather than represent the additional health care costs of the project as health opportunity losses, the health benefits can be valued as the additional health care resources which would have been required to deliver similar health benefits in that period by applying the relevant ‘threshold’ to the health benefits ($k_{ht} \cdot \Delta h_t$, in column (7)). The time streams of equivalent health care resource benefits and costs can then be discounted at a rate which reflects the opportunity cost, faced by the principal, of increasing public health care expenditure, r_s , (e.g., real yields on government bonds).

Table 1. Reporting the effects of a project with health benefits and health care costs

Effects of the project		Health Effects		Equivalent health care resources		Equivalent consumption effects		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Time	Additional health benefits	Additional health care costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
1	Δh_1	Δc_{h1}	Δh_1	$\Delta c_{h1}/k_{h1}$	$k_{h1} \cdot \Delta h_1$	Δc_{h1}	$V_{h1} \cdot \Delta h_1$	$V_{h1}(\Delta c_{h1}/k_{h1})$
..
t	Δh_t	Δc_{ht}	Δh_t	$\Delta c_{ht}/k_{ht}$	$k_{ht} \cdot \Delta h_t$	Δc_{t1}	$V_{ht} \cdot \Delta h_t$	$V_{ht}(\Delta c_{ht}/k_{ht})$
..
T	Δh_T	Δc_{hT}	Δh_T	$\Delta c_{hT}/k_{hT}$	$k_{hT} \cdot \Delta h_T$	Δc_{hT}	$V_{hT} \cdot \Delta h_T$	$V_{hT}(\Delta c_{hT}/k_{hT})$

Reporting cost-effectiveness ratios

Most cost-effectiveness analyses of health care projects report cost-effectiveness ratios rather than net health benefits (column (4)-(5)) or the equivalent net effect on health care resources (column (6)-(7)) (Phelps and Mushlin 1991, Stinnett and Mullahy 1998). An incremental cost effectiveness ratio ($\Delta c_h/\Delta h$) must be compared to a single ‘threshold’ relevant to the current period (k_{h1}). However, some account must be taken of expected changes in health opportunity costs. For example, if the cost-effectiveness ‘threshold’ is expected to grow in real terms ($gk_h > 0$), because the marginal productivity of health care expenditure is expected to decline (e.g., due to real growth in health expenditure), then future costs are less important because they will displace less health, or additional resources could deliver less health. Therefore, reporting cost-effectiveness ratios requires discounting the additional health care costs at a rate that accounts for any growth in the ‘threshold’,

⁶ This is the time preference for health, as distinct from pure time preference (for utility) or STP for consumption (see 5 below).

to reflect the relative importance of future costs ($r_h + gk_h$).⁷ This differential or dual discounting reflects expected changes in the marginal productivity of health care expenditure as well as time preference for health (Claxton et al 2011).

The widespread reporting of cost-effectiveness ratios in CEA may reflect reluctance on the part of decision making and advisory bodies to be explicit about how much health care systems can afford to pay to improve health and how this is likely to evolve over time. Until recently there has also been a lack of evidence about the likely health opportunity costs (Culyer et al 2007). As a consequence implicit assessments have been embedded in how costs and health effects are discounted. This has contributed to a lack of clarity about discounting policy, what a cost effectiveness 'threshold' ought to represent and how it might be informed with evidence.

One key recommendation is that this and other forms of dual discounting should be avoided (see section 4.2). Although cost-effectiveness ratios might be a familiar and useful summary the primary analysis should report time streams of health benefits and health care costs (columns (2) and (3) in Table 1), and their transformation into streams of health effects (columns (4) and (5) in Table 1) and streams of equivalent health care resources (columns (6) and (7) in Table 1) based on an explicit assessment of health opportunity costs.

Time stream of equivalent consumption effects

The health effects of the project in column (4) and (5) of Table 1 can also be expressed as the equivalent consumption value of the health benefits ($V_{ht} \Delta h_{ht}$, column (8)) and the health opportunity losses ($V_{ht}(\Delta c_{ht}/k_{ht})$, column (9)) in each time period. This requires some assessment of the consumption value of health (v_{ht}) and how it is likely to evolve over time. However, in this example, where there are only effects on health and health care costs, or where the social planner has decided that other effects should be set aside when considering this type of health care project⁸, v_{ht} does not influence the decision because it simply rescales any net health benefit or net health loss (both sides of $\Delta h > \Delta c_{ht}/k_{ht}$ are multiplied by v_{ht}). Since k_{ht} and v_{ht} cannot be assumed to be necessarily and always equal (see section 3.4 for discussion of the reasoning and empirical evidence that suggests $k_{ht} < v_{ht}$) health care costs cannot be treated as if they are private consumption costs and vice versa.

A 'threshold' that reflects an assessment of health opportunity costs is necessary when comparing different health care projects competing for limited health care resources. However, it is also relevant when considering broader questions of whether public resources available for health care should be increased. For example, it helps to inform: i) whether there a strong case for increasing health expenditure because $k_{h1} < v_{h1}$ and some projects are rejected that would have offered net social benefits if total health expenditure was increased to the point where $k_{ht}=v_{ht}$; and ii) how much of an increase in expenditure would be required to ensure $k_{ht}=v_{ht}$. The only circumstance in which evidence about k_{ht} could be disregarded is if it is assumed that health expenditure will be immediately increased to the point that $k_{ht}=v_{ht}$. However, it would be better to evaluate projects

⁷ This approximation is based on the plausible assumption that r_h and g_k are small.

⁸ There are reasons to set aside explicit and quantitative consideration of other effects if they are likely to conflict with other important social arguments that are difficult to specify let alone quantify, e.g., equity and the benefits of social solidarity offered by collectively funded health care. This is the explicit decision that has been taken in the UK by NICE and UK DH after considering the benefits and potential costs of quantifying these wider effects in the decision making process (refs Claxton et al 2015b and #Claxton et al 2010#).

founded on an empirically based assessment of k_{ht} and v_{ht} and how they are expected to evolve, rather than assume that public finances will be immediately set to achieve $k_{ht}=v_{ht}$ to accommodate the project being evaluated.

2.1.3 Non-health impacts and non-health care costs

Projects often impose costs or offer benefits beyond measures of health and health care expenditure. For example, there may be out of pocket costs and/or net production effects of improved survival and quality of life (e.g., Meltzer 2013) as well as impacts on other social objectives. Other types of project may have health and other effects but might not impose health care costs (e.g., nutrition, educational and environmental projects). Therefore, some assessment of how other types of benefits and costs should be traded against health and health care cost is required. When other effects include impacts on private consumption an explicit assessment of the consumption value of health allows health, health care costs and effects on private consumption to be expressed as time streams of either, their health, health care resource or consumption equivalents.

A project which has effects on health and health care costs but also imposes costs on private consumption (Δc_{ct}), or offers private consumption benefits (when $\Delta c_{ct} < 0$), is illustrated in Table 2a. The time stream of health benefits net of the health opportunity losses in column (5) combines the health benefits and additional health care costs of the project. The net effect on consumption (in column (6)) is the consumption costs (column (4)) net of the consumption opportunity costs associated with additional health care costs and the health opportunity losses associated with them. Therefore, once other effects beyond health and health care costs are included, some assessment of the consumption opportunity costs of health care expenditure (k_{ct}), or the consumption effects of changes in health, is also required⁹. The net effects of the project can then be reported as two time streams of net health and net consumption effects (columns (5) and (6)).¹⁰

⁹ These alternatives will be equivalent if the causal consumption effects of health care expenditure run only through the health effects of health expenditure, rather than, in part at least, directly from health expenditure itself. Insofar as health expenditure has a positive impact on economic growth compared to other forms of expenditure then restricting attention to the consumption effects of changes in health is likely to underestimate the consumption opportunity costs of health care costs.

¹⁰ It should be noted that attempts to estimate and explicitly account for the consumption opportunity costs of health care expenditure are particularly limited, even in high income settings, but do exist (Claxton et al 2015b). Although there is currently little evidence in lower income setting to support such assessment some default assumptions based on what is already known about the relationship between changes in health and economic growth should be possible.

Table 2a. Reporting the effects of a project on health, health care costs and consumption

	Effects of the project			Effects on health	Effects on consumption
(1)	(2)	(3)	(4)	(5)	(6)
Time	Additional health benefits	Additional health care costs	Consumption costs	Net health benefits	Net consumption costs
1	Δh_1	Δc_{h1}	Δc_{c1}	$\Delta h_1 - \Delta c_{h1}/k_{h1}$	$\Delta c_{c1} + k_{c1} \cdot \Delta c_{h1}$
..
t	Δh_t	Δc_{ht}	Δc_{ct}	$\Delta h_t - \Delta c_{ht}/k_{ht}$	$\Delta c_{ct} + k_{ct} \cdot \Delta c_{ht}$
..
T	Δh_T	Δc_{hT}	Δc_{cT}	$\Delta h_T - \Delta c_{hT}/k_{hT}$	$\Delta c_{cT} + k_{cT} \cdot \Delta c_{hT}$

Adopting an explicit consumption value of health (v_{ht}) allows the quantification and conversion of multiple effects to a common numeraire while reflecting the opportunity costs of constraints on health care expenditure. This is illustrated in Table 2b where the net health and consumption effects of the project (columns (5) and (6) of Table 2a) can be expressed as a time streams of equivalent net consumption effects (column (2)), discounted at r_c ; equivalent health effects (column (3)), discounted at $r_s - g_{kh}$; or the equivalent health care resources (column (4)), r_s .

Table 2b. Expressing the net effects of a project as consumption, health and health care costs

	Net effects		
(1)	(2)	(3)	(4)
Time	Equivalent consumption effects	Equivalent health effects	Equivalent health care resources
1	$v_{h1}(\Delta h_1 - \Delta c_{h1}/k_{h1}) - (\Delta c_{c1} + k_{c1} \cdot \Delta c_{h1})$	$(\Delta h_1 - \Delta c_{h1}/k_{h1}) - (\Delta c_{c1} + k_{c1} \cdot \Delta c_{h1})/v_{h1}$	$k_{h1}((\Delta h_1 - \Delta c_{h1}/k_{h1}) - (\Delta c_{c1} + k_{c1} \cdot \Delta c_{h1})/v_{h1})$
..
t	$v_{ht}(\Delta h_t - \Delta c_{ht}/k_{ht}) - (\Delta c_{ct} + k_{ct} \cdot \Delta c_{ht})$	$(\Delta h_t - \Delta c_{ht}/k_{ht}) - (\Delta c_{ct} + k_{ct} \cdot \Delta c_{ht})/v_{ht}$	$k_{ht}((\Delta h_t - \Delta c_{ht}/k_{ht}) - (\Delta c_{ct} + k_{ct} \cdot \Delta c_{ht})/v_{ht})$
..
T	$v_{hT}(\Delta h_T - \Delta c_{hT}/k_{hT}) - (\Delta c_{cT} + k_{cT} \cdot \Delta c_{hT})$	$(\Delta h_T - \Delta c_{hT}/k_{hT}) - (\Delta c_{cT} + k_{cT} \cdot \Delta c_{hT})/v_{hT}$	$k_{hT}((\Delta h_T - \Delta c_{hT}/k_{hT}) - (\Delta c_{cT} + k_{cT} \cdot \Delta c_{hT})/v_{hT})$

2.2 The objective of the project is to improve welfare

Traditionally the economic evaluation of social projects (e.g., Boadway and Bruce, 1984) adopts a view of social welfare resting on individual preferences revealed through markets or modified by an explicit welfare function. BCA is often founded on this more traditional approach and regards the purpose of any type of project, including those that require health care resources, as improving a broader notion of welfare rather than health or other explicitly stated social objectives. This type of analysis tends to be less well represented in the evaluation of health projects, partly due to the difficulty of decision making bodies being willing to identify a welfare function carrying some broad consensus, particularly if health is felt to be unlike other goods (e.g., Broome 1978, Sen 1979, Brouwer et al., 2008, Arrow 2012). Nevertheless, health must inevitably be traded with other welfare arguments, most notably consumption, by social planners whilst taking account of the constraints on health and other public expenditure they face.

BCA reports time streams of benefits and costs as their equivalent consumption values which represent the amount of consumption required to compensate for the costs of the project and the additional consumption that would need to be given to forego the benefits offered. The results of this type of analysis can be reported as the benefit cost ratio or net present value of the project. If consumption and health are the only arguments or are separable from others (Gravelle et al., 2007) then the time stream of equivalent net consumption effects of the project illustrated in Table 2b (see column (2)) or the equivalent consumption value of the benefits and costs of the project illustrated in Table 1 (see columns (8) and (9)) are the estimates required for a BCA of these projects.

Conducting analysis in this extensive way (illustrated in Table 1, 2a and 2b) ensures that any changes in the consumption value of health benefits and losses (v_{ht}) are already explicitly included in how the time streams of effects have been valued. Similarly any expected changes in the health and other opportunity costs of health care expenditure (k_{hb} , k_{ct}) have already been explicitly accounted for in the time stream of health and consumption effects (see column (2) of Table 2b). Once all the health and consumption effects of the project are expressed as equivalent time streams of consumption they can be discounted at a social time preference (STP) for consumption (r_c). The sum of the discounted time stream of the equivalent net consumption effects is the net present value of the project.

An alternative to this more extensive approach would be to try and account for changes the consumption value of health and the opportunity costs of health care expenditure through discounting. For example, for the project illustrated in Table 1, the discount rate for Δh_t could be amended to reflect expected growth in the consumption value of health, gv_h , by reducing the discount rate applied to health benefits ($r_c - gv_h$). The discount rate applied to ΔC_{ht} would also need to be amended to reflect both growth in the consumption value of health opportunity losses and any expected growth in a 'threshold' that reflects the health opportunity costs of health expenditure ($r_c - gv_h + gk_h$) (Claxton et al., 2011).¹¹ This differential or dual discounting implicitly accounts for changes in the value of health and changes in the marginal productivity of health expenditure as well as time preference. This and other form of dual discounting creates potential for confusion and becomes more difficult when changes in the consumption opportunity costs of health care expenditure must be accounted for and when these parameters do not grow at a constant rate. The separate and

¹¹ This approximation is based on the plausible assumption that r_h , g_v and g_k are small.

explicit accounting for each of these effects illustrated in Table 2b would appear more transparent, accountable and comparable.¹²

How to think about time preference for equivalent consumption effects is well established and well worked through the Ramsey Rule ($r_c = \delta + \eta g_c$). This includes pure time preference (δ , i.e., time preference for utility) and a wealth effect (ηg_c) which reflects the relative weight attached to consumption in future compared to the current period. Although an individual might exhibit forms of pure time preference there are good, albeit disputed, normative reasons to set pure time preference aside when making social choices that will have effects on current and future populations (Stern 2008, Nordhaus 2007, Arrow et al. 1999). The wealth effect in the Ramsey Rule requires some assessment of the growth in future consumption (g_c) and the weight that ought to be attached to them (η). This can be cast in a number of ways (e.g., based on individual diminishing marginal utility of consumption) and appeal to different forms of evidence (Groom and Maddison, 2013). However when considering social choices about projects which have impacts on current and future populations it might be best thought of as a form of inequality aversion where expectations of future growth in consumption means that additional consumption for future beneficiaries should be given less weight than the same additional consumption for current beneficiaries for whom consumption is more limited. The important thing to note is that r_c will always be country specific because even if η is common (and it need not be) r_c will be determined by expectations about future consumption growth which are likely to differ.

2.3 What is the distinction between CEA and BCA?

The explicit assessment of the relative value of other effects shows that the distinction between a CEA which accounts for wider effects and a BCA, which incorporates the opportunity of cost or shadow prices of existing constraints, is more apparent than real. Both require the same assessment of the same key parameters in Tables 2a and 2b. Although much of the applied work to inform decision making bodies has adopted a narrower health care system perspective (in part due to a concern for the perceived cost of conflicts with other important social objectives that are more difficult to fully specify and quantify) a broader 'societal' or multi sectoral perspective in CEA is possible and is required and recommended by a number of decision making bodies¹³.

What distinguishes BCA and CEA is a choice of whether social values ought to reflect those implied by the outcome of legitimate processes (e.g., government setting budgets for health care) or a notion of welfare founded on individual preferences or an explicit welfare function. For example, the former suggests a social time preference for health of $r_s - gk_h$ and the latter, $r_c - gv_h$. The distinction

¹² The UK DH and AAWG 'best practice' report suggests that health opportunity costs are dealt with explicitly and separately from discounting. Nonetheless they recommend a discount rate of 1.5% for health and health care costs and 3.5% for other effects, which embeds the expectation that the consumption value of health will grow at 2%. This happens to nullify the wealth effect in UK Treasury STP based on the Ramsey Rule.

¹³ Drummond et al 2015, Section 4.5.3 page 112-116. For example NICE requires a primary analysis from the perspective of the health care system. However, an analysis that includes other effects can be considered and are required for public health interventions and programs. Other decision making bodies in the Netherlands and Sweden require a broader perspective to be adopted as the primary analysis. A societal perspective was recommended as reference case analysis by the Washington Panel (Gold et al. 1996), alongside a health care system perspective is recommended in the reference case by the Washington Panel. The recent update to this guidance (Neumann et al 2016) recommends analysis from both a societal and health care system perspective.

is whether social value is expressed by k_t or v_t and whether it is the opportunity cost of financing health care or the welfare arguments that underpin the Ramsey Rule that justify discounting.¹⁴

The purpose is not to recommend which choice ought to be made but to clearly set out the implications for the common parameters that need to be assessed. The implications for discounting policy, whether conducting BCA or CEA, is that it becomes even more difficult and opaque to try and embed all these relevant arguments in how health, health care and other costs are discounted. The quantification and conversion of the time streams of multiple effects to a common numeraire (illustrated in Table 2a) avoids embedding multiple arguments in the discount rate for health and health care costs. For example, when it is believed to be important to explicitly quantify other impacts beyond measures of health and public health expenditure it would be appropriate to convert all effects into time streams of their equivalent consumption gains and losses, while reflecting the opportunity costs of existing constraints. These time streams of consumption benefits and costs can then be discounted at a social time preference rate for consumption based on the Ramsey Rule. The separate and explicit accounting for these arguments allows clarity about the parameters that need to be assessed, available evidence to be identified and used transparently and consistently, while preserving the possibility of accountable deliberation about evidence, values and unquantified arguments in decision making processes.

3. Evidence available to inform key parameters and possible default estimates

The common conceptual framework for CEA and BCA set out in Section 2 identifies the key parameters that need to be assessed to express the time streams of multiple effects to a common numeraire of equivalent consumption gains and losses which can then be discounted at STP for consumption. Each of these parameters, including STP for consumption, are likely to be country specific. As a consequence, the net present value of a project which has effects across a number of countries will be the sum of the country specific net present values (see Table 4)

3.1 Health opportunity costs of health care expenditure (k_{ht})

The problem of estimating a cost-effectiveness ‘threshold’ that represents expected health opportunity costs is the same as estimating the relationship between changes in health care expenditure and health outcome.¹⁵ Estimates of the marginal productivity of health expenditure in producing health (QALYs) are becoming available for some high income countries based on approaches to estimation which exploit within country data (Martin et al. 2008, Claxton et al. 2015a, Vallejo-Torres et al. 2017, and Edney, et al. 2018). The proportionate effect on all-cause mortality of proportionate changes in health expenditure (outcome elasticities) have also been estimated in higher income countries (Andrews, et al. 2017, Vallejo-Torres, et al. 2017 and Edney, et al. 2017 and Claxton Martin and Lomas, 2018) using similar approaches to estimation of within country data and have reported similar estimates. This evidence from higher income settings can be used to give some indication of possible values in lower income countries (Woods et al 2016) based on a number of assumptions about income elasticity of demand for health and the relative ‘under funding’ of

¹⁴ The actual differences may be modest if g_k and g_v are similar and the real rate at which government can borrow is regarded as a reasonable proxy for STPR as some argue it is (Council of Economic Advisers 2017).

¹⁵ See Drummond et al 2015 Section 4.3 page 83-94; Section 4.3.3.1 page 95-95

health care systems. This type of extrapolation suggests that cost per DALY averted is likely to be less than 1 GDP per capita in middle income countries and substantially lower in low income countries.

The effect of different levels of health care expenditure on mortality outcomes has been investigated in a number of published studies using country level data, many including LMICs (Gallet and Doucouliagos 2017). The challenge is to control for all the other reasons why mortality might differ between countries in order to isolate the causal effect of differences in health expenditure. This is a particular challenge even if available measures are complete, accurate and unbiased because health outcomes are likely to be influenced by expenditure (increases in expenditure improves outcomes), but outcomes are also likely to influence expenditure (poor outcomes prompt greater efforts and increased expenditure) (Nakamura et al, 2016). This problem of endogeneity, as well as the inevitable aggregation bias, risks underestimating the health effects of changes in expenditure.

Instrumental variables have been used in a number of studies to try and overcome this problem and estimate outcome elasticities for all cause adult and child mortality, by gender, as well as survival, disability and DALYs (Bokhari et al, 2007). These estimated elasticities have been used to provide country specific cost per DALY averted values for 123 countries, taking account of measures of a country's infrastructure, donor funding, population distribution, mortality rates, conditional life expectancies (all by age and gender), estimates of disability burden of disease and total health care expenditure (Ochalek et al 2015). These estimates have recently been updated and work is underway to assess how cost per DALY averted is likely to evolve with changes in health care expenditure and consumption growth (Ochalek et al 2017).

Possible default estimates (k_{ht})

Despite considerable data and estimation challenges some initial quantitative assessment of health opportunity costs and how they are likely to evolve is possible based on the balance of evidence such as it is. Updated estimates for almost all LMICs for 2015 expenditure are now available which might provide useful initial default estimates. Initial projections of these estimates based on other published projections of health expenditure and consumption are also available (Ochalek et al 2017). These initial country specific estimates can be refined and updated as other country specific estimates emerge, ideally using within country data where this is possible.

3.2 Consumption opportunity costs of health care expenditure (k_{ct})

The consumption opportunity costs associated with health care expenditure requires either direct evidence of the impact of changes on health care expenditure on net production (i.e., the value of additional production net of additional consumption) or estimates of the impact that changes in health are likely to have on net production in the rest of the economy (which with evidence from 3.1 the former can be derived from the latter).

Attempts to estimate and explicitly account for these non-health opportunity costs of health expenditure are particularly limited even in high income settings but do exist.¹⁶ There are no explicit

¹⁶ For example, as part of efforts to inform value based pricing of branded medicines (DH 2010 NICE 2014), the DH undertook work to estimate the 'wider social benefits' associated with changes in health outcome which

estimates for other countries, but a wide literature already exists at a micro level (e.g., health and labour market outcomes) and at a macro level (e.g., health and economic growth) which could be marshalled to derive estimates of the likely productive effects of changes in health relevant to different setting. These types of estimates could provide some default assessment of the net production effects likely to be associated with the particular type of health benefits offered by a project which has health effect. Importantly, they can also be linked to evidence of health opportunity costs in 3.1 to estimate the consumption opportunity costs of health care expenditure.

Possible default estimates (k_{ct})

In the absence of marshalling existing but disparate evidence a default assumption of 1 (1\$ spent on health care delivers 1\$ in net production or consumption opportunities) might not be unreasonable, albeit conservative assumption in LMIC settings given the very limited evidence currently available. Although there is little evidence about how this aspect of opportunity costs is likely to evolve, a default assumption that the real value of the net production effects of the health effects of changes in health expenditure will grow at the same rate as consumption may not be unreasonable.

3.3 Consumption value of health and its evolution over time (v_{ht})

There is a large literature which has used stated preferences (contingent valuation and discrete choice experiments) to estimate the consumption value or willingness to pay for improvements in health (e.g., Pinto-Prades 2009, Mason et al 2009). Recent reviews of this literature reveal wide variation in values (Vallejo-Torres et al, 2016; Ryen and Svensson, 2015;). The estimates reflect the demand for health and imply what health care expenditure ought to be, rather than a 'supply side' assessment of health opportunity costs. Most estimate how much consumption an individual is willing to give up to improve their own health. A few try to elicit how much individuals believe society should pay to improve health more generally. A wider literature, that extends beyond health, estimates the value of a statistical life (VSL) based on how much consumption individuals are willing to give up to reduce their mortality risk (Hammit 2000, Robinson et al 2016). Some studies are based on stated preferences (e.g., Lindhjelm 2011) but others identify situations where individuals make choices that imply a value, e.g. revealed preferences in the labour market. A cost per DALY can be derived from these studies by making assumptions about age and gender distribution, conditional life expectancies and quality of life norms.

Most of this literature reports values relevant to high income countries and other methods papers for the BCA reference case deal in more detail how a consumption value of health relevant to LMIC settings might be derived. However, some patterns that emerge are also likely to be relevant to LMICs: estimates based on VSL studies tend to be higher than those based on willingness to pay for health; values are not proportional to the scale of health gains and differ depending on whether health gains are through quality improvement or survival benefits.

Although there is limited direct empirical evidence which provides values in lower income settings there is some limited evidence about how values might evolve over time with growth in consumption. Reviews of the literature that have investigated the relationship between the VSL and

could be linked to evidence of health opportunity costs to estimate the net production opportunity costs of changes in health expenditure. The evidence in the UK suggests that a marginal £ in the NHS budget provides 92p worth of net production gains (see Appendix B of Claxton et al 2015b).

income (e.g., Viscusi and Aldy 2003; and Hammitt and Robinson 2011) suggests that earlier cross sectional studies of wage-risk premiums indicate income elasticities <1 , but longitudinal or cohort studies typically estimate elasticities >1 . (e.g., Costa and Kahn 2004). The reasons for these differences may be that cross-sectional studies are more likely to reflect changes in realised income, whereas longitudinal or across cohort studies are more likely to capture the impact of permanent income (e.g., Getzen 2000; Aldy and Smyth 2014). Despite the empirical difficulties the balance of evidence suggests that the consumption value of health increases with income. Assuming an income elasticity of demand of health between 1 and 2 may not be unreasonable.

There are also sound theoretical reasons why the value of health would be expected to grow with consumption (e.g., Parsonage and Neuburger 1992, Gravelle and Smith 2001, Hall and Jones 2007). The intuition can be expressed in the same way as the expected increase in value of environmental goods; that the growth in consumption is likely to outstrip the growth in health so health will become scarcer relative to consumption. Since consumption is an imperfect substitute for health the value of health will increase. These arguments can be made using behavioural models of individual choices of health affecting activities over time e.g., purchasing health care. The growth in the value of health will be determined by income growth, the income elasticity of demand for health care and the elasticity of the marginal productivity of health care. Alternatively health can be included as a separate argument in a social welfare function where it is valued in its own right, in part, because a healthier state increases the marginal utility of income and an indirect effect through income due to uninsured health care costs and/or increased productivity of being in a healthier state. These insights indicate there are compelling reasons to believe the consumption value of health will grow with income and it is likely to grow at a faster rate if there is a direct effect of health on utility and an indirect effect through income.

Possible default estimates (v_{ht})

Although theoretical arguments point to a number of empirical questions, a simple but reasonable assessment of how v_{ht} is likely to evolve could be based on growth in consumption (which is already required and embedded in the wealth effect of the Ramsey Rule) and assumptions about the income elasticity of demand for health. An income elasticity of demand for health of 1 might be a reasonable albeit conservative default assumption in which case v_{ht} would grow at the same rate as consumption. This could be compared with a less conservative scenario based on income elasticity of 2, where the value of health benefits and health opportunity costs would grow at twice the rate of consumption. Other scenarios could be justified based on evidence that income elasticity is likely to differ in particular settings.

3.4 Other constrained sectors (v_{xt}/k_{xt})

Health expenditure is not the only category of public expenditure which is constrained. Therefore, the effects of a project on other types of public expenditure ought to reflect their opportunity costs in the same way as health expenditure. One way to do this is to use the evidence that is available for the health sector to shadow price other form of public expenditure. Estimates of the consumption value of health tend to be higher than available estimates of a 'supply side' assessment of health opportunity costs (Vallejo-Torres et al, 2016). This suggests a common discrepancy between the demand and supply side of health care systems. For example, if these estimates are regarded as an appropriate expression of social value, the difference between v_{ht} and k_{ht} would

indicate that health care from collectively pooled resources is ‘underfunded’ compared to individual preferences about health and consumption.¹⁷ It is consistent with the view that the public funding of health care is not matching individual preferences and public expectations of their health care system. However, given the difficulties faced in the public financing of health care and the welfare losses associated with socially acceptable means of taxation this is what might be expected and especially so in lower income settings where the difficulties of public financing are more acute. The balance of evidence suggests that $v_{ht}/k_{ht} > 1$. This ratio is the shadow price for public health expenditure, i.e., the value of health expenditure \$ relative to private consumption \$. Therefore, estimates of v_{ht} and k_{ht} , which are already required, can also be used to shadow price other forms of public expenditure.

Possible default estimates (v_{xt}/k_{xt})

Estimates of v_{ht}/k_{ht} in the health sector might be used to shadow price other forms of public expenditure (where the equivalent estimates for that sector are absent) since resource allocation and expenditure decisions by government and other ministries would be expected to equalise this ratio across sectors (x) given an overall constraint on total public expenditure, i.e., it may not be unreasonable to assume $v_{ht}/k_{ht} = v_{xt}/k_{xt}$ when considering impacts on public sector x.

3.5 Time preference for consumption (r_c)

A social time preference rate for consumption based on the Ramsey Rule ($r_c = \delta + \eta g_c$) includes pure time preference (δ) and a wealth effect (ηg_c). Although an individual might exhibit forms of pure time preference, there are good, albeit disputed, normative reasons to set pure time preference aside when making social choices that will have effects on current and future populations (Stern 2008, Nordhaus 2007, Arrow et al. 1999). The wealth effect in the Ramsey Rule reflects an assessment of the expected growth in consumption (g_c) and the weight that ought to be attached to consumption in the future compared to the current period (η). This ‘weight’ can be founded on different forms of evidence but might be best thought of as a form of inequality aversion where expectations of growth in means that additional consumption for future beneficiaries should be given less weight than the same additional consumption for current beneficiaries for whom consumption is more limited.

There is some empirical evidence to inform η in high income countries (Groom and Maddison 2013) which includes reviews of expert opinion (Drupp et al. 2015). However, the balance of this evidence in high income settings suggests that there is some element of inequality aversion with values of $1 < \eta < 2$ not being unreasonable (Groom and Maddison 2013). There are also possibilities of obtaining revealed values for η through other social choices (e.g., the progressivity of tax and benefit systems) (Evans and Sezer 2002) or focusing on growth in median income (Emmerling Groom and Wethingfield, 2017) rather than applying an estimated η to expected growth in mean income. Little direct evidence of η exists for LMICs; nonetheless country specific default estimates of r_c are possible because even if η is common (and it need not be) it will be determined by expectations about

¹⁷ For example, the UK DH has adopted £15,000 per QALY to assess health opportunity costs and until recently £60,000 per QALY as an estimate of the consumption value of health based on deriving QALY effects from VSL estimates. This would suggest that one health care £ is worth £4 of private consumption effects, which is especially important when there are other impacts which fall outside constrained public expenditure.

economic growth which are likely to differ between countries with different expectations about economic growth.

Possible default estimates

A conservative default assumption to establish country specific estimates of r_c would be to apply $\eta = 1$ to available estimates of g_c (reported as expected growth in measures of national income per capita for that country), i.e., the discount rate applied to time streams of equivalent consumption effects is g_c . This could be compared with a less conservative scenario based on $\eta = 2$, where r_c would be twice the expected growth in consumption. Other scenarios could be justified based on evidence or reasoning of why η is likely to differ in specific contexts or based on different judgements about the prospects of future economic growth by social planners. As evidence for values of η specific to LMICs evolves and estimates of economics growth are revised these defaults can be updated. This can also be compared to a wealth effect based only on expected growth in median income where those are available.

3.6 Catastrophic, macroeconomic and project specific risk

Catastrophic risk

Truly catastrophic risk is best thought of as the probability of an event which would mean that all public and private projects will have zero cost and benefits, i.e., an event that represents total catastrophe for the whole of society. When cast in this way it excludes events which could be described as 'catastrophic' but where some recovery might be possible even if this requires assistance from others (other countries, global bodies). This is important, as although a 'catastrophic' event where recovery is possible may have a major impact on the costs and benefits of public and private projects, these impacts are unlikely to be the same for all projects. Therefore, these types of 'catastrophic' but recoverable risks are best included in the evaluation of the project itself rather than being embedded in a common discount rate for consumption effects.

There are sources for probabilities of truly catastrophic events where recovery would not be possible (Chapman 2004, Stern 2007). The probabilities are relatively small and if included would add little to a common discount rate for consumption effects. Given the other more influential sources of uncertainty in specifying reasonable default values for a common discount rate for consumption effects it might be reasonable to set aside truly catastrophic risks. If catastrophic risk is included, it should be based an estimate of the probabilities of truly catastrophic events where recovery would not be possible ($\leq 0.1\%$).

Macroeconomic risk

When all effects of a project are expressed as streams of consumption benefits and costs then discounting using STP for consumption would be appropriate. However, some decline in r_c over longer time horizons will be required to reflect the impact of increasing uncertainty in r_c due to uncertainty in the consumption growth element of the wealth effect of the Ramsey Rule. (Arrow et al. 2013, Cropper et al. 2014, Freeman and Groom 2016, Freeman et al 2015). Since uncertainty in r_c will increase over time, due to increasing uncertainty about future consumption, some decline is

required to return the correct expected net present value (Weitzman 1998).¹⁸ This effect of uncertainty can also be described as macroeconomic risk or prudential savings. The impact is more modest over shorter terms but is more significant when there is greater uncertainty about economic growth (Gollier 2014).

The time horizon for the evaluation of many projects with health effects are often less than 30 years or generally do not extend much beyond that. For example, insofar as a project impacts on mortality risk the time horizon for costs and benefits need only extend to the survival of the cohort of current beneficiaries. However, projects which change the dynamics of infectious disease and/or require commitment of irrecoverable costs also require an assessment over the survival of future incident cohorts that will be affected or will benefit from the investment. Therefore, for projects which have longer terms, or where macroeconomic risk is greater and increases more rapidly with term (as is more likely in LMICs) declining rates might be justified but should be founded on uncertainty in consumption growth rather than behavioural evidence of time preference.

Therefore, the use of r_c without adjustment for macroeconomic risk maybe a reasonable default assumption for projects with time horizons less than 30 years. Where there are longer time horizons or where macroeconomic risk is greater and increases more rapidly with term, declining rates might be required but should be based on uncertainty in the STP for consumption. Since growth and uncertainty about that growth will be country specific any decline in r_c will also be country specific.

Project specific risk

Considerable efforts have been made in the evaluation of health projects to characterise all sources of uncertainty, value the consequences and establish how these should inform project choice, e.g., whether the approval should be delayed until further research is conducted or until sources of uncertainty resolve overtime. The impact of irrecoverable costs and the real option value of delay have been examined as well as the impact of approval on the opportunities to acquire evidence that would benefit future patient populations. The impact of uncertainty on resource allocation across projects under alternative budgetary policies and the implications uncertain non-marginal budget impacts have also been examined (see Drummond et al 2015, Chapter 11 for an accessible summary). This type of analysis starts to unpick the reasons for the appearance of risk aversion in project choice.

Some project evaluations, may have already accounted for the consequences of some project specific risks in ways that others may not. In any event these risks and their consequences necessarily differ by project so should certainly not be embedded in a common discount rate for the consumption effects. Therefore, where possible, project specific risks should be included in how the expected time streams of consumption equivalent effects of the project are estimated. If these risks have been accounted for in this way it could be argued that they can be discounted at a risk free rate (Arrow and Lind 1970) and no project specific risk premium would be required. This would be reasonable if government or other funders of the project can diversify risk (e.g., across many tax payers) and that project specific risks are uncorrelated with those in the wider economy. If they are

¹⁸ Applying the average r_c will not return the expectation of NPV over the range of values r_c might take. Therefore declining rates are required when g_c and therefore r_c is uncertain so that discounting using declining rates returns the correct expected NPV.

correlated then a project specific risk premium may be required to account for the interaction between project specific and macroeconomic risk (Baumstark and Gollier, 2014).

The interaction of project specific and macroeconomic risk is not often considered in the evaluation of social projects but is a well-established feature of how capital assets are priced. The parallel for social projects is to consider the relationship between the uncertainty in the project's payoffs and uncertainty in future macroeconomic conditions. For example, a project with payoffs that are counter cyclical (provides greater than expected payoffs when growth and consumption is lower than expected) are more valuable than a project with the same expected payoffs, but which offers pro cyclical risks (offers poorer than expected outcomes when growth is lower than expected).

This can be reflected in a project specific risk premium which depends on the correlation between project payoffs and realised consumption growth. If this correlation is positive (negative) then the project discount rate should be above (below) the STP for consumption based on the Ramsey Rule, whether or not it has been adjusted for macroeconomic risk (Gollier 2012). The project can be said to have a positive (negative) beta, indicating that future payoffs should be discounted at a higher (lower) rate. The magnitude of this effect also depends on how any correlation tends to be concentrated. For example, if it is concentrated in low probability but high impact events such as a severe fall in consumption when the payoffs from the project also drop (rise) at the same time, then the risk premium will be highly positive (negative), which can significantly reduce (increase) the value of the project (Barro 2009).

This is likely to be especially important in LMIC settings where uncertainty about economic growth and the possibility of low probability but high impact events may be higher than in high income countries. Uncertainty about the outcomes of projects in LMICs might also be greater and more strongly correlated with macroeconomic risk. Therefore, an important question is whether the payoffs from a project are likely to be positively or negatively correlated with economic growth, and whether any correlation is concentrated in low probability high impact events. For example, the present value of a project which is likely to offer greater payoffs in times of war, economic crisis or severe epidemic will be substantially higher than indicated by discounting at a STP for consumption. In the absence of established estimates of betas for health projects and a lack of experience in the field in estimating them, a qualitative indication of whether or not projects are likely to be strongly pro or counter cyclical and how these cyclical effects are likely to be concentrated would be a useful starting point for deliberation by decision makers, while further research is conducted on how the effects of these interactions might be best quantified for these types of project relevant to LMICs.

4 Recommendations, reporting and further research

4.1 A summary possible default estimates

The possible default values for the key parameters and assessment required, which were identified in Section 2 and discussed in Section 3, are summarised in Table 3.

Table 3 Key parameters and possible default estimates and assumptions

Key parameters and assessments required		Possible estimates and default assumptions
Health opportunity costs of health care expenditure	k_{ht}	<ul style="list-style-type: none"> Estimates for most LMICs for 2015 expenditure provide initial default estimates of cost per DALY averted Initial projections of these estimates based on other published projections of health expenditure and consumption are also available These initial estimates can be refined and updated as other country specific estimates emerge, ideally using within country data where this is possible
Consumption opportunity costs of health care expenditure	k_{ct}	<ul style="list-style-type: none"> A conservative default assumption of 1 (1\$ spent on health care delivers 1\$ in net production) A conservative default assumption that the real value of the net production effects will grow at the same rate as consumption
Consumption value of health and its evolution over time	v_{ht}	<ul style="list-style-type: none"> Country specific estimate of v_h (see the recommendations from other BCA methods papers) Growth in v_{ht} can be based on growth in consumption (g_c) and two alternative scenarios of the income elasticity of demand for health A conservative scenario using an income elasticity of demand for health of 1 (v_{ht} will grow at g_c) Scenario using an income elasticity of demand of 2 (v_{ht} will grow at twice g_c)
Other sectors (x)	v_{xt}/k_{xt}	<ul style="list-style-type: none"> Default assumption that $v_{ht}/k_{ht} = v_{xt}/k_{xt}$ when considering impacts on other public sectors
Time preference for consumption	r_c	<ul style="list-style-type: none"> A normative assumption of zero pure time preference for social choices is not unreasonable ($\delta = 0$) Two scenarios based on alternative assumptions of inequality aversion can be used <ul style="list-style-type: none"> A conservative scenario based on $\eta = 1$ ($r_c = g_c$) Alternative scenario based on $\eta = 2$ ($r_c = 2g_c$) Other scenarios can be based on evidence of why η is likely to differ in specific contexts or different judgements about g_c
Catastrophic risk		<ul style="list-style-type: none"> It would not be unreasonable to set aside truly catastrophic risk from a common discount rate for consumption If catastrophic risk is included, it should be based an estimate of the probability of truly catastrophic events where recovery would not be possible ($\leq 0.1\%$)
Macroeconomic risk		<ul style="list-style-type: none"> Use of r_c without adjustment for macroeconomic risk maybe a reasonable default assumption for projects with shorter time horizons (<30 years) For longer time horizons or where macroeconomic risk is

		greater and increases more rapidly with term, declining rates may be required but should be based on uncertainty in consumption growth
Project specific risk		<ul style="list-style-type: none"> • Where possible project specific risks should be included in how the time streams of consumption equivalent effects of the project are estimated • A qualitative indication of whether projects are likely to be strongly pro or counter cyclical should be provided • Further research is required on how the interaction of project specific and macroeconomic risk might be best quantified for the types of project relevant to LMICs

These parameters, which are common to CEA and BCA depend, directly or indirectly on expectations about the growth in consumption. For example, STP for consumption and the growth in the consumption value of health both depend directly on g_c . The change in health and other opportunity cost associated with health care expenditure will also, in part, be determined by expectations about economic growth. This has two implications. Firstly, since g_c will be country specific all these parameters will also be country specific including r_c , which has important implications for aggregating effects of a project that is relevant to a number of different jurisdictions (see Section 4.2). Secondly, it is important that any assessment of g_c is consistently applied to inform all the key parameters that depend on it, so that any change in these expectations, or any alternative judgments about g_c , feeds through into all the relevant parameters and is used consistently throughout.

4.2 Reporting and aggregating effects

Extensive reporting is recommended as illustrated in Tables 1, 2a and 2b. Reporting the results of CEA and BCA in this way makes explicit the assessments required. This enables the impact of alternative, but plausible, assumptions to be explored and analysis to be updated as better estimates evolve. The quantification and conversion of the time streams of multiple effects into their equivalent health, health care cost or consumption effects avoids embedding multiple arguments in discounting policies. The separate and explicit accounting for these arguments provides clarity about the parameters that need to be assessed, available evidence to be identified and used transparently and consistently, while preserving the possibility of accountable deliberation about evidence, values and unquantified arguments in decision making processes.

Some projects and supra national investments will have effects across different counties where all these key parameters will differ, e.g., when global bodies make recommendations, purchase health technologies, or prioritise the development of new ones. Other projects and national investments will have effects across jurisdictions (e.g., states or provinces) within a particular country where only some of these parameters differ (e.g., k_{nt}). Therefore, the net present value of a project which has effects across a number of countries will be the sum of the country specific net present values rather than the sum of effects across countries discounted at some common rate.

Table 4. Reporting the effects of a project with impacts on more than one jurisdiction

Equivalent consumption effects across countries or jurisdictions			
	Country A	Country B	Country C
Effects in period t	$v_{h,t}^A \left[\Delta h_t^A - \frac{\Delta c_{h,t}^A}{k_{h,t}^A} \right] - [\Delta c_{c,t}^A + k_{c,t}^A \cdot \Delta c_{h,t}^A]$	$v_{h,t}^B \left[\Delta h_t^B - \frac{\Delta c_{h,t}^B}{k_{h,t}^B} \right] - [\Delta c_{c,t}^B + k_{c,t}^B \cdot \Delta c_{h,t}^B]$	$v_{h,t}^C \left[\Delta h_t^C - \frac{\Delta c_{h,t}^C}{k_{h,t}^C} \right] - [\Delta c_{c,t}^C + k_{c,t}^C \cdot \Delta c_{h,t}^C]$
Net present value	$\sum_{t=1}^T \frac{v_{h,t}^A \left[\Delta h_t^A - \frac{\Delta c_{h,t}^A}{k_{h,t}^A} \right] - [\Delta c_{c,t}^A + k_{c,t}^A \cdot \Delta c_{h,t}^A]}{(1+r_c^A)^t}$	$\sum_{t=1}^T \frac{v_{h,t}^B \left[\Delta h_t^B - \frac{\Delta c_{h,t}^B}{k_{h,t}^B} \right] - [\Delta c_{c,t}^B + k_{c,t}^B \cdot \Delta c_{h,t}^B]}{(1+r_c^B)^t}$	$\sum_{t=1}^T \frac{v_{h,t}^C \left[\Delta h_t^C - \frac{\Delta c_{h,t}^C}{k_{h,t}^C} \right] - [\Delta c_{c,t}^C + k_{c,t}^C \cdot \Delta c_{h,t}^C]}{(1+r_c^C)^t}$
Global net present value	$\sum_{t=1}^T \frac{v_{h,t}^A \left[\Delta h_t^A - \frac{\Delta c_{h,t}^A}{k_{h,t}^A} \right] - [\Delta c_{c,t}^A + k_{c,t}^A \cdot \Delta c_{h,t}^A]}{(1+r_c^A)^t} + \sum_{t=1}^T \frac{v_{h,t}^B \left[\Delta h_t^B - \frac{\Delta c_{h,t}^B}{k_{h,t}^B} \right] - [\Delta c_{c,t}^B + k_{c,t}^B \cdot \Delta c_{h,t}^B]}{(1+r_c^B)^t} + \sum_{t=1}^T \frac{v_{h,t}^C \left[\Delta h_t^C - \frac{\Delta c_{h,t}^C}{k_{h,t}^C} \right] - [\Delta c_{c,t}^C + k_{c,t}^C \cdot \Delta c_{h,t}^C]}{(1+r_c^C)^t}$		

This is illustrated in Table 4 for a project with effects on health, health care costs and consumption in three countries or jurisdictions (A, B and C). The country specific effects must be transformed into country specific time streams of equivalent consumption and then discounted at the country specific rate for consumption. The country specific NPVs can then be summed to indicate the global NPV of a project with effects in a number of countries.

4.3 Suggestions for further research

An initial quantitative assessment of health opportunity costs and how they are likely to evolve is possible based on the balance of evidence from studies using country level data. Currently available estimates can be updated with more recent data on country level expenditure, demographics and epidemiology. The initial projections of these estimates can also be updated so that changes in opportunity costs can be linked to same expectations of consumption growth which determines estimates of STP for consumption and growth in the consumption value of health. More recent estimates of the health effects of changes in health care expenditure suggest that larger effects tend to be identified when using within country data and especially at a disease area level. This is what might be expected, given the greater dangers of aggregation bias of using country level data and the difficulty of fully accounting for unobserved heterogeneity and endogeneity using the instruments for health expenditure that are available across countries. Therefore, exploring the implications of elasticities estimated from within country data for other countries where such estimates are not yet available would be valuable. Extending the estimation of outcome elasticities using within country data to more health care systems would be particularly valuable.

Attempts to estimate the non-health opportunity cost of health expenditure are particularly limited. Nonetheless, a wide literature already exists at a micro level (e.g., health and labour market outcomes) and at a macro level (e.g., health and economic growth) which could be marshalled to derive estimates of the likely productive effects of changes in health relevant to different settings. Marshalling this evidence would provide an assessment of the net production effects likely to be

associated with the particular type of health benefits offered by a project as well as the net production losses from the health opportunity costs associated with the projects demands on health care expenditure.

Estimates of country specific expected growth in consumption are available and can inform a number of parameters including STP for consumption. Although there is some empirical evidence to inform the weight that might be attached to future compared to current consumption (η), little direct evidence exists for LMICs. There are, however, possibilities of obtaining revealed values for η through other social choices (e.g., the progressivity of tax and benefit systems) or focusing on growth in median income rather than applying an estimated η to growth in mean income. It would be useful to review existing estimates of median income in LMICs and examine how its expected growth might be linked to current estimates of economic growth. This would enable alternative ways to estimate a STP for consumption to be considered. The evidence to support estimates of the consumption value of health in particular LMICs and income elasticities of demand for health are also limited. Other BCA methods papers consider in more detail how these might be estimated in LMICs and discuss further research that might be conducted.

The use of r_c without adjustment for increasing uncertainty about future consumption maybe a reasonable default assumption for projects with shorter time horizons. However, for longer time horizons or where macroeconomic risk is greater and increases more rapidly with term (as is more likely in LMICs) declining rates might be required. A review of estimates of g_c relevant to LMICs could identify the circumstances where declining rates should be applied. This could be used to develop tools which would provide appropriate declining rates for r_c based on g_c , measures of uncertainty in g_c by term, η and an initial assumption that projects are neither pro or counter cyclical ($\beta=0$).

An important question is whether the payoffs from a project are likely to be positively or negatively correlated with economic growth, and whether any correlation is concentrated in low probability high impact events. Such correlation and the project risk premiums they imply can have a significant impact on the value of a project. This issue is not often considered in the evaluation of social projects and there is a lack of experience of estimating this type of risk premium (betas) for the types of projects considered in LMICs. Therefore, a first step would be to illustrate, with case studies, how a qualitative indication of whether or not projects are likely to be strongly pro or counter cyclical might be made and how these cyclical effects are likely to be concentrated. This might also identify the characteristics of projects and circumstances where quantifying the interaction of project and macroeconomic risk is likely to be particularly important in project choice and how betas might be estimated for these types of project.

References

- Aldy, J.E., Smyth, S.J. (2014) Heterogeneity in the value of life. Resources for the Future, Discussion Paper No. 14-13.
- Andrews, M. et al. (2017) Inference in the presence of redundant moment conditions and the impact of government health expenditure on health outcomes in England. *Econometric Reviews*, 36(1–3), pp.23–41.
- Arrow K, R Lind (1970). Uncertainty and the evaluation of public investment decisions. *American Economic Review*, 60, 364–378.
- Arrow, K.J. (2012) *Social Choice and Individual Values*, with an introduction by Eric S Maskin, Newhaven: Cowles Foundation; 2012.
- Arrow K, M Cropper, C Gollier, B Groom, G Heal, R Newell, W Nordhaus, R Pindyck, W Pizer, P Portney, T Sterner, R Tol, M Weitzman (2013). Determining benefits and costs for future generations. *Science*, 341(6144), 349–50.
- Barro RJ (2009). Rare disasters, asset prices, and welfare costs. *American Economic Review*, 99, 243–264.
- Baumstark L, C Gollier (2014). The relevance and the limits of the Arrow-Lind Theorem. *Journal of Natural Resources Policy Research*, 6, 45–49.
- Bertram, M.Y. et al. (2016) Use and misuse of thresholds Cost–effectiveness thresholds: pros and cons. *Bulletin of the World Health Organization*. Dec 1; 94(12): 925–930.
- Boadway RW, Bruce N. (1984). *Welfare Economics*. Blackwell: Oxford.
- Bokhari FAS, Gai Y, Gottret P. (2007) Government health expenditures and health outcomes. *Health Economics*, 16: 257-273.
- Broome, J. (1978). Trying to value a life. *Journal of Public Economics*, 9, 91–100.
- Brouwer WBF, Niessen LW, Postma MJ, Rutten FFH. (2005) Need for differential discounting of costs and health effects in cost effectiveness analyses. *British Medical Journal* 331: 446-448.
- Brouwer W, Culyer AJ, Job N, van Exel A, Rutten FH. (2008). Welfarism vs. extra-welfarism. *Journal of Health Economics*, 27: 325–338.
- Chapman CR. (2004). The hazard of near-Earth asteroid impacts on earth. *Earth Planet Sci Lett.*, 222(1):1-15
- Claxton, K, Paulden, M, Gravelle, H, Brouwer, W & Culyer, AJ (2011). Discounting and decision making in the economic evaluation of health-care technologies' *Health Economics*, 20(1): 2-15.
- Claxton K, Martin S, Soares MO, Rice N, Spackman E, Hinde S, Devlin N, Smith PC, Sculpher M. (2015a). Methods for the estimation of the NICE cost effectiveness threshold. *Health Technology Assessment*, 19(14).

- Claxton K, Sculpher M, Palmer S, Culyer AJ. (2015b). Causes for concern: is NICE failing to uphold its responsibilities to all NHS patients? *Health Economics*, 24(1):1-7.
- Claxton K, Lomas JRS, Martin S. (2018). The impact of NHS expenditure on health outcomes in England: Alternative approaches to identification in all-cause and disease specific models of mortality. *Health Economics*. Feb 7.
- Coast, J., Smith, R., and Lorgelly, P. (2008), 'Welfarism, extra-welfarism and capability: the spread of ideas in health economics', *Social Science and Medicine*, 67, 1190-98.
- Costa DL, Kahn ME. (2004). Changes in the value of life, 1940–1980. *Journal of Risk and Uncertainty*, XXIX, 159–180.
- Council of Economic Advisers Discounting for public policy: theory and recent evidence on the merits of updating the discount rate. Council of Economic Advisers Issue Brief, January 2017.
- Cropper M, MC Freeman, B Groom, W Pizer (2014). Declining discount rates. *American Economic Review: Papers & Proceedings*, 104, 538–543.
- Culyer AJ, McCabe C, Briggs A, Claxton K, Buxton M, Akehurst R, Sculpher M, Brazier J. (2007). Searching for a threshold, not setting one: the role of the National Institute of Health and Clinical Excellence. *Journal of Health Services Research and Policy* 12: 56-58.
- Department of Health. 2004. *Policy Appraisal and Health: A Guide from the Department of Health* (Reissued). Department of Health: London.
- Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. (2015). *Methods for the Economic Evaluation of Health Care Programmes*. 4th ed. Oxford: Oxford: Oxford University Press.
- Edney, LC. et al. (2018). Estimating the Reference Incremental Cost-Effectiveness Ratio for the Australian Health System. *Pharmacoeconomics*. Feb;36(2):239-252.
- Emmerling J, Groom B and Wettingfield T (2017) Discounting and the representative median agent. *Economics Letters*, 161. pp. 78-81
- Evans D J and Sezer H (2002). A time preference measure of the Social Discount Rate for the UK. *Applied Economics*, 34, 1925-1934.
- Freeman MC, B Groom (2016). How certain are we about the certainty-equivalent long term social discount rate? *Journal of Environmental Economics and Management*. Online at doi: <http://dx.doi.org/10.1016/j.jeem.2016.06.004>
- Freeman MC, B Groom, E Panopoulou, T Pantelidis (2015). Declining discount rates and the Fisher Effect: Inflated past, discounted future? *Journal of Environmental Economics and Management*, 73, 32-49.
- Gallet, C.A. & Doucouliagos, H. (2017) The impact of healthcare spending on health outcomes: A meta-regression analysis. *Social Science & Medicine*. 179, pp.9–17.

- Getzen, T.E. (2000) Health care is an individual necessity and a national luxury: applying multilevel decision models to the analysis of health care expenditures. *J Health Econ.* 19(2): p. 259-70.
- Gollier C (2012). Evaluation of long-dated investments under uncertain growth trend, volatility and catastrophes. CESifo Working Paper: Industrial Organisation, No. 4052.
- Gollier C (2014). Discounting and growth. *American Economic Review: Papers & Proceedings*, 104, 534–537.
- Gravelle H, Smith D. (2001). Discounting for health effects in cost-benefit and cost-effectiveness analysis. *Health Economics* 10: 587-599.
- Gravelle H, Brouwer WBF, Niessen LW, Postma MJ, Rutten FFH. (2007). Discounting in economic evaluations: stepping forward towards optimal decision rules. *Health Economics* 16(3): 307-317.
- Groom B, DJ Maddison (2013). Non-identical quadruplets: Four new estimates of the elasticity of marginal utility for the UK. Centre for Climate Change Economics and Policy Working Paper No. 141.
- Hall RE, Jones CI. (2007). The value of life and the rise in health spending. *Quarterly Journal of Economics*, February, Vol. 122 (1), pp. 39-72.
- Hammitt JK. 2000. Valuing mortality risk: theory and practice. *Environmental Science and Technology* 34: 1396–400.
- Hammitt, J.K., Robinson, L.A. (2011). The income elasticity of the value per statistical life: transferring estimates between high and low income populations. *Journal of Benefit-Cost Analysis*, 2(1): p. 2152-2812.
- Lipscomb J, Weinstein MC, Torrance GW. (1996). Time preference. In *Cost-Effectiveness in Health and Medicine*, Gold MR, Siegel JE, Russell LB, Weinstein MC (eds). Oxford University Press: Oxford, 214–246.
- Lindhjelm H, Navrud S, Braathen NA, Biauxque V. 2011. Valuing mortality risk reductions from environmental, transport, and health policies: a global meta-analysis of stated preference studies. *Risk Analysis* 31: 1381–1407.
- Mason H, Jones-Lee M, Donaldsson C. (2009). Modelling the monetary value of a QALY: a new approach based on UK data. *Health Economics* 18: 933–950.
- Meltzer, D. O. (2013), 'Future costs in medical cost-effectiveness analysis ', in A. Jones (ed.), *The Elgar Companion to Health Economics* (Cheltenham: Edward Elgar Publishing Ltd), 481-89.
- Nakamura R, Lomas JRS, Claxton K, Bokhari F, Moreno Serra RA, Suhrcke ME. Assessing the impact of health care expenditures on mortality using cross-country data. (2016). York, UK: Centre for Health Economics, University of York. Apr, p. 1-57. (CHE Research Paper; 128).
- Neumann PJ, Sanders GD, Russell LB, Siegel JE, Ganiats TG, editors. *Cost-effectiveness in health and medicine*. Second edition. 2nd edition. New York: Oxford University Press; 2016.

- Nord, E. (2011), Discounting future health benefits: the poverty of consistency arguments. *Health Economics*, 20, 16–26.
- Nordhaus WD. (2007). A review of the Stern review on the economics of climate change. *J Econ Lit.*, 45(3):686-702.
- Ochalek JM, Lomas J, Claxton K. (2015). Cost per DALY averted thresholds for low- and middle-income countries: evidence from cross country data. York, UK: Centre for Health Economics, University of York. Dec, p. 1-50. (CHE Research Paper; 122).
- Parsonage M, Neuburger H. (1992). Discounting and health benefits. *Health Econ*, 1: 71–76.
- Paulden, M. and Claxton, K. (2012), 'Budget allocation and the revealed social rate of time preference for health', *Health Economics*, 21, 612-18.
- Paulden M, O'Mahony JF, and McCabe C. (2017). Discounting the Recommendations of the Second Panel on Cost-Effectiveness in Health and Medicine. *Pharmacoeconomics*, 35:5–13
- Paulden M, Galvanni V, Chakraborty S, Kudinga B, McCabe C. Discounting and the Evaluation of Health Care Programmes. CADTH. 2016.
https://www.cadth.ca/sites/default/files/pdf/CP0008_Economic_Evaluation_Guidelines_Discount_Rate_Report.pdf
- Pinto-Prades JL, Loomes G, Brey R. (2009). Trying to estimate a monetary value for the QALY. *Journal of Health Economics* 28: 553–562.
- Phelps, C.E. and Mushlin, A.I. (1991), On the (near) equivalence of cost-effectiveness and cost-benefit analyses. *International Journal of Technology Assessment in Health Care*, 7, 12-21.
- Rawlins, M. D. and Culyer, A. J. (2004), National Institute for Clinical Excellence and its value judgments. *British Medical Journal*, 329, 224 - 27.
- Robinson LA, Hammitt JK, Chang AJ, and Resch S. (2016). Understanding and improving the one and three times GDP per capita cost-effectiveness thresholds. *Health Policy Planning*. First published online: July 24, 2016.
- Ryen, L. and Svensson, M. (2014), 'The willingness to pay for a quality-adjusted life year: a review of the empirical literature DOI: 10.1002/hec.3085', *Health Economics*.
- Sen, A. (1979), Personal utilities and public judgments. Or what's wrong with welfare economics. *The Economic Journal*, 89, 537–58.
- Spackman M. (2017). Social discounting: the SOC/STP divide. Grantham Research Institute on Climate Change and the Environment, Working Paper No. 182, February.
- Stern NH (2007). *The economics of climate change: the Stern review*. Cambridge University Press, Cambridge, UK.
- Stern NH (2008). *The economics of climate change*. *Am Econ Rev*. May;98(2):1-37.

Stinnett AA, Mullahy J. (1998). Net health benefits: a new framework for the analysis of uncertainty in cost-effectiveness analysis. *Medical Decision Making* 18(suppl): S68-S80.

Martin S, Rice N, Smith PC. (2012). Comparing costs and outcomes across programmes of health care. *Health Economics*. Mar;21(3):316-337.

Martin S, Rice N, and Smith PC. (2008). Does health care spending improve health outcomes? Evidence from English programme budgeting data. *Journal of Health Economics*, 27:826–42.

Vallejo-Torres L, García-Lorenzo B, Castilla I, Valcárcel-Nazco C, Lidia García-Pérez L, Linertová R, Polentinos-Castro E, Pedro Serrano-Aguilar P.(2016). On the Estimation of the Cost-Effectiveness Threshold: Why, What, How? *Value in Health*. First published online: 23 April, 2016.

Viscusi, W.K. and Aldy JE. (2003). The value of a statistical life: A critical review of market estimates throughout the world. *Journal of Risk and Uncertainty*, 27(1): p. 5-76.

Woods BS, Revill P, Sculpher MJ, Claxton K. (2016). Country-level cost-effectiveness thresholds: initial estimates and the need for further research. *Value in Health*, Feb 20.