Health Policy and Planning Advance Access published July 24, 2016

Health Policy and Planning, 2016, 1–5
doi: 10.1093/heapol/czw096
Methodological Musings

OXFORD

Understanding and improving the one and three times GDP per capita cost-effectiveness thresholds

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Accepted on 16 June 2016

Abstract

Researchers and policymakers have long been interested in developing simple decision rules to aid in determining whether an intervention is, or is not, cost-effective. In global health, interventions that impose costs per disability-adjusted life year averted less than three and one times gross domestic product per capita are often considered cost-effective and very cost-effective, respectively. This article explores the conceptual foundation and derivation of these thresholds. Its goal is to promote understanding of how these thresholds were derived and their implications, as well as to suggest options for improvement. These thresholds are intended to reflect the monetary value of the benefits to affected individuals, based on their preferences for spending on health vs spending on other goods and services. However, the current values were not rigorously derived, which means that their application may lead to inappropriate conclusions regarding which interventions should be adopted as well as misallocation of resources across health and other investments. Improving the basis for these cost-effectiveness thresholds is of particular importance in low- and middle-income countries, given the limited resources available and the significant needs of their populations.

Key words: Cost-effectiveness analysis, disability-adjusted life years, international health policy, resource allocation, willingness to pay

Key Messages

- In global health, cost-effectiveness analysis is often used to compare the costs of an intervention with a non-monetary measure of its effectiveness, such as the disability-adjusted life years (DALYs) averted. Thresholds indicate the cost per unit of effectiveness below which an intervention may be worthy of further consideration.
- One approach to developing such thresholds is to estimate the value affected individuals place on the effectiveness measure; e.g. on a DALY. This concept is the foundation for the one and three times gross domestic product (GDP) per capita thresholds commonly used in global health. This value is derived from estimates of individual willingness to pay for a change in one's own risk, averaged throughout the affected population and expressed as the value of a life year. GDP per capita is used to scale the values to the resources available in each country.
- In the near term, these multipliers could be improved by incorporating the findings from recent research. In the longer term, additional primary research on the values held by low- and middle-income populations would be useful.
- These values are uncertain and are only one of many factors that should be considered in determining whether to implement an intervention. However, better understanding the preferences of affected populations is useful even if the results are not used as thresholds.

Introduction

Given the numerous health interventions that might benefit populations in low- and middle-income countries, it is not surprising that both scholars and policymakers are interested in finding simple rules-of-thumb that can be used to easily distinguish between those interventions that are, and are not, worth pursuing. We explore the derivation and conceptual foundation of one such decision rule: the one and three times gross domestic product (GDP) per capita cost-effectiveness thresholds often applied in global health.

Our goal is not to advocate an approach for establishing thresholds. Rather, we hope to provide insights that will aid analysts and decision makers in understanding the implications of the one and three times GDP per capita thresholds and in identifying opportunities for improvement. The approach that underlies these values is intended to provide information on the preferences of the population affected by an intervention, which is likely to be useful regardless of whether the estimates are used as thresholds. We begin by reviewing the role of thresholds in cost-effectiveness analysis, then discuss the derivation of the one and three times GDP per capita values and describe potential improvements.

The role of thresholds

Cost-effectiveness analyses provide information on the cost per unit of effect for health-related interventions.[1] The effect may be measured as life years gained if the intervention is primarily targeted on mortality risks, or as an improvement in disability-adjusted life years (DALYs) or quality-adjusted life years (QALYs) if the intervention is expected to significantly affect health quality. Although DALYs and QALYs differ in concept and application, both translate the impact of non-fatal health effects into a life year measure, so that the years of life lived in different health states or lost to premature fatality can be combined into a single indicator.

The DALY measure is more commonly used in global health. It was originally developed to assess the global burden of disease (Murray and Lopez 1996; Murray *et al.* 2012; Salomon *et al.* 2012) and is now often used when estimating the cost-effectiveness of health-related interventions. For non-fatal effects, the loss from disability is measured as a value between zero (for full health) and one (equivalent to dead). For example, a health condition assigned a disability weight of 0.2 is equivalent to 80% of a year in full health. The disability weight is multiplied by the duration of the condition, taking life expectancy into account. For fatal effects, each year of life lost is assigned a value of 1.0 DALY.

If the goal is to maximize population health and longevity subject to a fixed health care budget, then in principle the decision maker could simply fund interventions starting with the most cost-effective and stopping when reaching the budget constraint (Weinstein and Zeckhauser 1973). The least cost-effective intervention funded would then essentially define the threshold. However, these conditions rarely, if ever, hold. Study quality varies, many potentially cost-effective interventions have not been assessed, factors other than cost-effectiveness legitimately influence decision-making, and budgets are often at least somewhat flexible. An alternative approach is to set a threshold and to consider funding those interventions that are more cost-effective than the threshold.

1 This framework is described in detail in numerous health economics texts, such as Drummond *et al.* (2015). For more discussion of the use of cost-effectiveness analysis in global health, see, e.g. WHO (2003) and Musgrove and Fox-Rushby (2006).

Numerous approaches have been proposed for establishing cost-effectiveness thresholds (Smith and Richardson 2005; Shillcutt *et al.* 2009; Claxton *et al.* 2010; Woods *et al.* 2015). Generally, they can be categorized as 'demand-side' or 'supply-side' approaches or as a combination. Demand-based values focus on the preferences of the affected population; i.e. on what they are willing to pay per unit of effect. Supply-based values focus on the opportunity cost of the intervention; i.e. on the cost per unit of effect of the most beneficial alternative that would not be funded if the intervention was implemented. In theory, these values would be equal if the preferences of the affected population were known, health policy decisions fully reflected these preferences, and health budgets were optimal. In reality, demand- and supply-based values are likely to differ, given that individual preferences vary in ways that are not well-understood, budgets may be non-optimal and health policy decisions reflect numerous other factors.

Derivation of the one and three times GDP per capita thresholds

For many years, cost-effectiveness thresholds of one and three times GDP per capita per DALY averted have been frequently cited in global health. For example, the World Health Organization's (WHO's) Choosing Interventions that are Cost-Effective (CHOICE) program defines interventions for which the cost per DALY averted is less than GDP per capita as very cost-effective, between one and three times GDP per capita as cost-effective, and greater than three times GDP per capita as not cost-effective.[2]

These are demand-based values taken from the 2001 report of WHO's Commission on Macroeconomics and Health (CMH). The CMH does not explicitly address cost-effectiveness thresholds; rather, it develops estimates for use in benefit-cost analysis. The CMH notes

> According to some estimates, each life year is valued at about three times the annual earnings. This multiple of earnings reflects the value of leisure time in addition to market consumption, the pure longevity effect, and the pain and suffering associated with disease. (CMH 2001, p. 31)

The CMH approximates earnings using per-capita gross national income (GNI), which is similar to GDP.[3] GNI or GDP is used to scale the value of a life year to income. A constant multiplier assumes proportionate changes: a one percent income difference leads to a one percent difference in the value of a life year.

The CMH reports its analytic results using one times GNI per capita as a 'very conservative' estimate of the value of a life year and also applies the three times GNI per capita value per life year noted earlier. The CMH does not describe the derivation of these values, noting only that '[s]uch high valuations have been used in several recent economic analyses' (p. 31). It references four examples. The first is Cutler and Richardson (1997), who apply a value per life year of $100 000 in 1990 dollars as their benchmark US value based

2 See http://www.who.int/choice/cost-effectiveness/en/ and WHO (2002).

3 GNI is identical to gross national product (GNP). GDP is the value of economic activity within a country. GNI is instead the value of economic activity of a country's residents; it includes income received from abroad and excludes payments sent to other countries. These measures are not limited to private earnings or consumption; they also include investments and government spending.

on Tolley *et al.* (1994). This is somewhat less than the midpoint of the \$70 000–\$175 000 range Tolley *et al.* derive using various value per statistical life (VSL) estimates and discount rates. It is approximately four times 1990 US per capita GDP or GNI, which were both ∼\$24 000 at that time.[4] The second reference is to a 1999 working paper by KM Murphy and R Topel (unpublished), who use a life cycle model that combines theoretical expectations with VSL research and data on US earnings, consumption and life expectancy at different ages to estimate the value of increasing life spans.[5] They find that the present value of a 1 year change in life expectancy is ∼\$150 000–\$200 000 in 1992 dollars. This range is approximately six to eight times 1992 US per capita GDP or GNI, which were somewhat above \$25 000. The third and fourth references, G Becker *et al.* (unpublished) and Philipson and Soares (2001), are closely related.[6] Both are working papers that focus on calculating full income for the purpose of cross-country comparisons, where full income includes both GDP per capita and the value of life expectancy. Each relies on a life cycle model to estimate the value per life year but neither provides a mean nor median value that can be compared with the values from the other studies.

Thus the research cited by the CMH supports a value per life year greater than GNI or GDP per capita, perhaps by multipliers larger than three. The CMH multipliers were not rigorously derived; they were illustrative estimates based on the then-available research. The CMH is very clear that its calculations were intended as rough examples.[7]

Underlying concepts

The research cited by the CMH is taken from the extensive VSL literature. Essentially, researchers convert a VSL to a constant value per life year and adjust it for income, ignoring the other factors that may influence these values. VSL is an individual's marginal rate of substitution between money and risk of dying in a defined time period (Hammitt 2000). It characterizes an individual's willingness to spend on small increases in survival probability rather than purchasing other goods and services.

Conventionally, VSL is calculated by estimating individuals' willingness to pay (WTP) for a small change in their own mortality risk and dividing by the risk change. For example, if an individual is willing to pay \$900 for a 1 in 10 000 reduction in his risk of dying in the current year, his VSL is \$9.0 million (\$900 WTP ÷ 1/10 000 risk change). Although the ratio of WTP to risk reduction may exceed the individual's income, WTP is obviously limited by income (or more accurately wealth). Presumably, WTP accounts for both the pecuniary effects of the risk change (including out-of-pocket medical expenses and future earnings) and the non-pecuniary effects (including the joy of living). Several reviews indicate that most VSL studies consider the risks of accidental deaths, largely among adult populations in high-income countries (Viscusi and Aldy 2003; Hammitt and Robinson 2011; Lindhjem *et al.* 2011).

The value of a life year concept introduced earlier is identical to the concept of the value per statistical life year (VSLY). The inclusion of the term 'statistical' emphasizes the role of probability; interventions generally reduce the risk of death rather than eliminating it with certainty (Hammitt 2007, 2013). Because few empirical studies directly estimate VSLY, it is typically derived from an estimate of VSL, often by dividing that VSL by the (discounted) expected life years remaining for an individual at the mean age of the population studied.[8] This approach does not adjust for likely changes in the quality of life as one ages, implicitly averaging over future health.

Some studies estimate a VSL that varies by age and derive a corresponding age-specific VSLY by dividing by the (present value of) expected life years remaining from that age. Age-specific VSLs may be estimated empirically (Aldy and Viscusi 2007, 2008) or derived from a life cycle model (seminal examples include Shepard and Zeckhauser 1984; Rosen 1988). Of the studies cited by the CMH to support its illustrative values, one (Cutler and Richardson 1997) relies on estimates derived from individual VSL studies; the others rely on life cycle models.

VSL and VSLY are expected to vary with income, reflecting differences in ability to pay. For example, Robinson and Hammitt (2016) suggest that the US population-average VSL is ∼\$9 million (2013 dollars). This implies that the average US citizen is willing to pay \$900 for a 1 in 10 000 mortality risk change, which was 1.7% of US GDP per capita (\$53 000) in 2013. In Kenya, where GDP per capita was ∼\$2800 in the same year, it seems unlikely that the average individual would be willing to spend \$900 on the same risk reduction, given the difficulties of funding basic needs. It is more likely that individual WTP per unit of risk reduction will decrease as income decreases, resulting in a lower VSL. The use of GDP or GNI multipliers to scale the value of a life year to cross-country income differences is consistent with this assumption.

VSL estimates that exceed the present value of future income and consumption, as well as VSLY estimates that exceed annual income or consumption, are consistent with the conceptual framework discussed earlier. An individual's WTP reflects the value of living, which includes more than the effects on earnings or productivity. Thus the use of GDP or GNI multipliers >1.0 seems reasonable.

Using these VSLY-based thresholds to estimate the value per DALY averted and adjusting only for national income is based on two simplifying assumptions. The first is that VSLY is constant; i.e. that the value of a 1-year change in life expectancy is not affected by factors other than national income. As discussed in the references cited earlier, both VSL and VSLY are likely to depend on the characteristics of the population affected (such as age, life expectancy and health status), the characteristics of the risk (such as whether it is viewed as voluntary or controllable) and the physical and social characteristics of the society (such as the quality of its health care system).

The second is that the value of a DALY is equivalent to this constant VSLY regardless of whether the effect is non-fatal or fatal; e.g. a year of life lived with a disability measured as 0.2 DALYs can be

4 GNP (GNI) and GDP per capita data throughout are in current international dollars, based on purchasing power parity, downloaded from the World Bank's World Development Indicators database on 10 March 2015 (http://data.worldbank.org/data-catalog/world-development-indicators).

5 The Murphy and Topel paper is available at http://faculty.chicagobooth.edu/kevin.murphy/research/murphy&topel.pdf).

6 The CMH report references a 2001 version of the Becker *et al.* (2003) paper ("Growth and Mortality in Less Developed Nations"); this discussion reflects the 2003 version of that paper because we were unable to locate the earlier version.

7 The Lancet Commission on Investing in Health (Jamison *et al.* 2013) reports values per life year using a more thoroughly documented approach. However, the values it reports reflect a number of strong assumptions and are based on a specific gain in population life expectancy; the approach was designed to value population-wide gains in longevity over time, not to provide a generic threshold.

8 See Jones-Lee *et al.* (2015) for more discussion of the appropriate derivation of a VSLY from a VSL.

valued by multiplying the VSLY by 0.8 (=1–0.2). Both theory and an increasing body of scholarship suggest that this assumption does not hold. In particular, several studies suggest that the value of a QALY depends on the severity and duration of the health condition as well as other factors (Haninger and Hammitt 2011; Robinson *et al.* 2013; Pennington *et al.* 2015). The value of a DALY, although less studied, is likely to vary for similar reasons. Thus while thresholds based on a constant national value per life year may provide a useful screening tool, they should not be viewed as an accurate measure of a population's preferences for spending on health improvements.

Opportunities for improvement

The one and three times GDP per capita multipliers currently used as cost-per-DALY averted thresholds are based on outdated research and were not rigorously derived; as a result, there are many opportunities for improvement. We suggest some options below that can be implemented based on currently available research and briefly discuss the need for new primary research. Our intent is not to wade into the arguments regarding the relative merits of different approaches for estimating thresholds. Rather, we suggest options for improving the derivation of thresholds if the intent is to represent the value that affected individuals place on the risk reductions. Note that although we focus on thresholds, these approaches also can be used to value risk reductions in benefit-cost analysis.

In the near term, one important but simple improvement involves more explicitly accounting for uncertainties in the relationship between VSL and income by applying a range of income elasticity estimates. The CMH extrapolates from a US VSL estimate assuming an income elasticity of 1.0; as discussed in Hammitt and Robinson (2011), larger elasticities may be appropriate. Changing the elasticity can lead to values that vary by an order of magnitude or more. For example, starting with a US VSL of $9.0 million and using the GDP per capita estimates above, the Kenyan VSL would be ~$480 000 with an elasticity of 1.0, $110 000 with an elasticity of 1.5 and $25 000 with an elasticity of 2.0.[9] If we assume that the remaining life span for the average Kenyan is 30.5 years, then the resulting VSLY would be $24 000, $5600 or $1300 depending on the elasticity (3% discount rate).[10]

However, the low end of this range is less than GDP per capita ($2800), which is inconsistent with theory. As Hammitt and Robinson (2011) discuss, per capita income or consumption should be used as a lower bound on these values, given that VSL and VSLY reflect the value of living in addition to productivity and consumption. This means that cost-effectiveness thresholds for Kenya based on these values would be between $2800 and $24 000 depending in the elasticity, or 1.0 and 9.0 times GDP per capita. For countries with higher incomes, the low end of the range of extrapolated VSLYs is likely to exceed GDP per capita, thus the range of multipliers will vary across countries. The wide range of resulting values suggests that it may be desirable to task a group of experts with reviewing the literature and determining whether a narrower range of elasticities might be appropriate.

A second important improvement would be to conduct a criteria-driven review of the VSL and VSLY studies globally. The available reviews cited earlier are outdated, and our understanding of what constitutes a high quality study is evolving as a result of new research and expert reviews. Evaluation criteria that reflect our current understanding of best practices are described in recent reviews of US VSL studies (Robinson and Hammitt 2016, U.S. Environmental Protection Agency 2016).[11] These criteria can be adapted for application to studies conducted elsewhere, and also adjusted to address the available VSLY studies as well as any studies that explicitly explore the monetary value of a DALY. We expect that this review will indicate that extrapolation of values across countries continues to be necessary, but will aid in improving the approach for such extrapolation. It would provide insights into the effects of income differences on these values as well as the effects of other influencing factors.[12]

More generally, the CMH approach relies on strong assumptions because of the lack of research on the values held by low- and middle-income populations. In the longer term, more primary VSL research in these countries, as well as VSLY and value per DALY research, is needed. Ideally, such research would adhere to the best-practice recommendations that relate to the criteria referenced earlier. However, methods appropriate for use in the US and other high-income countries may need to be adjusted for application in low- and middle-income countries due to cultural differences, data availability, technological capacity and other considerations.

For example, US VSL studies often examine the relationship between wages and job-related risks; conducting such research requires data of reasonable quality on the wages earned in different occupations and industries, the associated risks and the other factors (such as educational attainment) that may influence wages. Such data may not be available in less developed countries. This means that valuation studies may need to rely largely on survey methods, which can be challenging to implement. Researchers in high-income countries have developed approaches for addressing issues such as the hypothetical nature of the payment and difficulties understanding probabilities, which may need to be adapted to other settings (see Hoffmann *et al.* 2012 for an example). Experience with valuing environmental and other policies in low-income settings also provide useful lessons related to addressing low literacy levels and non-cash economies (Whittington 2010; Durand-Morat *et al.* 2015).

Determining whether thresholds should be based on these sorts of demand-based estimates, or on a different framework (such as the opportunity costs of forgone health investments) raises a number of difficult issues beyond the scope of this article. However, regardless of which approach is applied, information on the preferences of the population affected is likely to be useful. For example, the population may be more willing to participate in programmes that are consistent with their preferences. Thus additional research seems desirable.

9 The formula is $VSL_B = VSL_A * (Income_B/Income_A)^{elasticity}$. '$VSL_B$' is the result of extrapolating from 'VSL_A' given the ratio of the income levels for groups *A* and *B* and the elasticity estimate.

10 For this illustrative example, we assume remaining life expectancy is one-half of Kenyan life expectancy at birth, based on 2013 data from WHO's Global Health Observatory Data Repository (http://apps.who.int/gho/data/node.main.688?lang=en). We apply this value as a very rough approximation of the remaining life years for a Kenyan of average age, given that the population-average US VSL that we use as a starting point is for an individual at an age that is approximately one-half of US life expectancy at birth.

11 Approaches for combining results across VSL studies are discussed in Robinson and Hammitt (2015).

12 Hoffmann *et al.* (2012) describe a series of studies conducted in several countries using a similar survey instrument. Meta-analysis of the data collected in these studies may provide additional insights into these issues.

Acknowledgements

The authors thank participants in the June 2015 iDSI Workshop on Cost-Effectiveness Thresholds and the September 2015 meeting on Economic Evaluation in Health at Harvard University for useful discussions of these issues. They also thank two anonymous reviewers for their helpful comments on earlier drafts of this article.

Conflict of interest statement. None declared.

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