Preference-Based Assessments

The Value of a Statistical Life-Year in Sub-Saharan Africa: Evidence From a Large Population-Based Survey in Tanzania

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A B S T R A C T

Background: The value of a statistical life-year (VSLY) is the central number for the economic allocation of health resources. Nevertheless, empirical data on VSLY are lacking for most low- and middle-income countries. In the absence of empirically established VSLY, researchers typically use an arbitrary 3-times multiple of per-capita gross domestic product or per-capita income per life-year saved to establish cost-effectiveness. **Objective:** In this study, we establish an empirical VSLY for the first time for a community in sub-Saharan Africa. **Methods:** To empirically establish VSLY, we randomly selected 4000 individuals in the Ukonga community of Tanzania and employed a contingent valuation survey to measure VSLY.

Using the contingent valuation methodology, we elicited willingness to pay for a 2% mortality risk reduction and had individuals convert this into an annualized payment to be paid each year over

their expected remaining life. **Results:** We compared our elicited value to per-capita income and found that mean VSLY is $9340 (95% CI $6206-$12 373). The mean annual income in our sample was $2069, resulting in a VSLY that is equivalent to 4.5 times per-capita income. **Conclusion:** Our results provide empirical evidence to support moving away from using the World Health Organization cost-effectiveness thresholds in practice because they will likely result in inefficient underinvestment in cost-effective interventions, even in relatively poor samples.

Keywords: cost-effectiveness, economic evaluation, health policy, public health, stated preference.

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Introduction

The value of life is of central importance to the discipline of health economics. Understanding the value of life, expressed in monetary terms, allows for prioritization decisions to be made between different types of lifesaving interventions. In practice, most economic evaluations of health interventions use either the value of a statistical life (VSL) or the value of a statistical life-year (VSLY) for resource allocation decision making. The VSL is the marginal rate of substitution between income and risk of death. It is often measured as an individual's willingness to pay (WTP) for a small change in their risk of dying over a defined period, scaled up to a 100% risk to represent 1 statistical life.[1] The VSLY is the marginal rate of substitution between income and life expectancy, or the annualized VSL, and is typically measured as the total VSL divided

by discounted future life-years remaining. In cost-effectiveness analysis, to categorize cost-effectiveness ratios into cost-effective and not cost-effective, a monetary threshold for the VSLY is usually applied. In benefit-cost analysis, benefits measured in life-years saved are often translated into monetary values using the VSLY.

Despite the importance of VSLY for health policy analysis, empirical data on VSLY are lacking for sub-Saharan Africa (SSA), the region with the lowest life expectancies and largest global burden of disease.[2] In the absence of empirically established VSLY, researchers typically use thresholds based on multiples of per-capita gross domestic product (GDP). The World Health Organization (WHO) defines an intervention as "highly cost-effective" if it saves 1 life-year with an investment of less than 1 time per-capita GDP and as "cost-effective" if it saves 1 life-year for

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an investment between 1 time and 3 times per-capita GDP.[3] These 2 multiples were suggested by the WHO *Commission on Macroeconomics and Health* and have since become the dominant values used in thousands of economic evaluations of health interventions worldwide, and particularly those in low- and middle-income settings.[4-6]

Per-capita GDP, a measure of domestic production, is often employed as a proxy estimate of average market income in a country. The GDP is used as a proxy for income at the national level owing to the limitations on data availability for measuring market income directly. Life, however, has value apart from the market income a person earns, such as the value of non-market production, the value of leisure time and happiness, and the value of passing on social norms and knowledge to children.[7] Additionally, other non-GDP approaches for estimating cost-effectiveness thresholds, such as the full-income approach, rely on strong assumptions about life expectancy, which may not hold.[8,9]

There are 2 primary approaches to estimate VSLY without using national-level income estimates: revealed preference and stated preference. Revealed-preference approaches use labor market data to extrapolate the tradeoffs made by specific individuals between wages and mortality risk. Stated-preference approaches ask study participants in surveys directly about their WTP for reductions in mortality risk. The data required for revealed-preference studies are difficult to obtain in SSA owing to the large informal economy and a lack of consistent labor market reporting. Additionally, separate age-specific life expectancy data are required to convert VSL from revealed preferences into a VSLY. These data are often unavailable for the subpopulation of interest, and relying on population averages as approximations can greatly affect results given the sensitivity of VSLY to assumptions about life expectancy.[10]

Stated-preference surveys eliciting WTP through hypothetical market choices are also more difficult to conduct in SSA because sampling frames from which to generate population-representative samples are harder to obtain. Additionally, both numeracy and literacy levels are typically lower than in developed settings, placing greater demands on the framing and the elicitation approach of the WTP question.[11] In particular, to adequately describe mortality risk reductions in settings of low numeracy requires presentation of proportions or rates that are intuitive to the populations examined.[12] Moreover, framings that have been commonly used in developed countries, such as sudden death from cancer or heart disease, may not be credible or meaningful in SSA owing to large differences in the epidemiology of leading causes of death. Finally, the normative expectations for which types of interventions to reduce mortality risk individuals should pay for—rather than governments or insurance companies—are likely very different in SSA.[13,14]

A final issue of concern is how to elicit the value of the externalities associated with a life-year, that is, an individual's valuation of the fact that another person lives for an additional year. The external value of a life-year is usually ignored in revealed-preferences studies, and its omission may lead to large biases in VSLY estimates for SSA.[15-18] Unlike in settings with extensive social welfare systems, in much of SSA individuals rely greatly on kinship and social networks for support, particularly during periods of illness and in old age.[19,20] Therefore, this value of someone else's life, motivated by self-interest rather than pure altruism, is likely to be higher in SSA than in developed countries and should be captured in stated-reference elicitation.[21,22]

Taking these difficulties into account, we developed and used a setting-specific stated-preference contingent valuation methodology to establish VSLY in the Ukonga district of Dar es Salaam, Tanzania. The results of this study represent the first VSLY elicitation via stated preference in SSA, the first test of the validity of

the WHO-CHOICE thresholds in the region. Our study also outlines a methodology for assessing VSLY in other low- and middle-income regions.

Methods

Study Area and Population

The study area consisted of the total population of the Ukonga Health and Demographic Surveillance System (HDSS) survey area in peri-urban Dar es Salaam, Tanzania. The HDSS covers 21 181 households and has a total population of 92 685, which are administratively subdivided into streets. We obtained the identification numbers and list of all individuals in the Ukonga HDSS from the affiliated members of the Dar es Salaam Urban Cohort Study.

We limited our sample to adults 18 years or older. Age restrictions were employed to ensure that respondents would understand the questions asked and have an understanding of the demands and responsibilities of day-to-day life. From this eligible population, we employed cluster randomization to select a representative sample of households from each of the 7 streets in the Ukonga area. Adults within each household were then randomly listed, and surveyors who approached the selected households asked to interview the first member on the list. If that individual was not present, then the next individual from the list was asked to participate. Our initial sample consisted of 4000 individuals. Sample size calculations yielded 3200 individuals needed to estimate VSLY with a 1% margin of error, and we initially assumed a 20% non-response rate. Nevertheless, of the 4000 selected only 15 refused to answer questions regarding VSLY. These individuals believed that it would be bad luck to respond to questions relating to a hypothetical risk of death. Our final sample contained 3985 observations. This high response rate is likely the result of prenotifying respondents of their selection into the study, that this population is regularly surveyed as part of an ongoing demographic surveillance, and our sampling process.

Study Questionnaire

Ethical approval for both the data collection and for the analysis of the deidentified survey data was obtained from the institutional review board of the authors' home university and the institutional review board of the host institution in Tanzania. Sampled individuals gave voluntary consent to participate in the survey. The survey questionnaire included baseline demographic questions on age, sex, marital status, parental status, perceived health status, household food security, and employment status. Household food security was assessed using the household food insecurity access category, a validated measure of household food security.[23] Respondents were also asked to report their monthly earnings in 2 ways. The first method was through summing the values of an itemized list of potential revenue categories that were self-reported by the respondent for the previous month. The itemized list included income earned from formal employment, pensions, rents, informal business, transfers, and gifts.[24] The second method was to ask individuals to estimate their average monthly income. There was very little discrepancy in elicited income between these 2 methods.

The last section of the survey included 1 contingent valuation payment card question to elicit WTP for a small reduction in the risk of death over 1 year. Respondents were asked each value on the payment card in ascending order and told to say no when the value became too expensive. The respondents were then asked if their true value was between the previous value and their stopping point. After asking the payment card question, the

interviewers were asked to rate how well they believed that the respondent understood the question, based on the respondent's ability to report back to the surveyor a clear explanation of what was being asked. Procedures for rating respondents on a 1-10 scale were rigorously defined and validated across field workers in the pilot stage. Components of this assessment included clear understanding of the probability, ability to grasp the idea of risk and explain it, ability to understand this was a recurring annual lifetime payment for a risk reduction, and ability to understand and explain how the dollar value related to their ability to pay. The survey questionnaire is shown in English in the Appendix in Supplemental Materials found at https://doi.org/10.1016/j.vhri.2019.07.009. The survey was conducted in Kiswahili. In total, 12 trained surveyors and 4 field supervisors were used to carry out the data collection for this study.

Pilot Study

An initial pilot of the questionnaire among the 12 fieldworkers and 4 supervisors was conducted to ensure that the contingent valuation question was expressed in a comprehensible way and that the survey questions were not offensive or invasive in the local context. This first pilot resulted in changing the framing of the 2% mortality risk reduction from being the result of a road traffic accident to a more acceptable general reduction in the risk of dying. We also included a long preamble to the question to make sure that the respondent is comfortable with the scenario and mentally prepared to answer a question concerning mortality. These adaptations significantly reduced the refusal rate in our pilot of this question.

After the initial revision, a second pilot of the contingent valuation question was conducted with 36 individuals from the study population. During this stage, participants were asked to explain back the question to the surveyor in their own words to demonstrate an understanding of the scenario, the specific details, and the intention of the question. The primary revision from this pilot round was having the surveyor repeat the question using an analogy of a community, if the respondent did not adequately understand the scenario using the initial framing. This adaptation was phrased as "imagine there are 2 communities in which you could live, everything is exactly the same about the 2 communities except that in the community that you currently live in 4 out of 100 people will die every year and 1 of them might be you. In the other community only 2 out of 100 people will die every year, and 1 of them might be you. What is the most TZS that you are willing and able to pay, per year, to move from the community where 4 people will die to the identical community where only 2 people will die per year?" Visuals to accompany the VSLY elicitation components of the survey were also added to the questionnaire and were both explained to and shown to participants immediately before eliciting their response. These visuals displayed the 2 of 100 person community and the 4 of 100 person community.[11] This addition improved the ability of respondents to correctly repeat the question's intention in their own terms, which was a signal of comprehension.

Analysis

Our primary question of interest used a contingent valuation payment card approach to elicit annual WTP for a 2% reduction in risk of death. The question asks the individual to respond to the scenario as a recurring annual payment for a recurring annual risk reduction, which is paid from the present in perpetuity for the remaining expected lifespan of the respondent. We then calculated VSLY from the questionnaire directly. Benefits of this approach are that individuals can use private information such as family history and current health knowledge to assess their own

Table 1 – Socioeconomic and demographic information from sample.

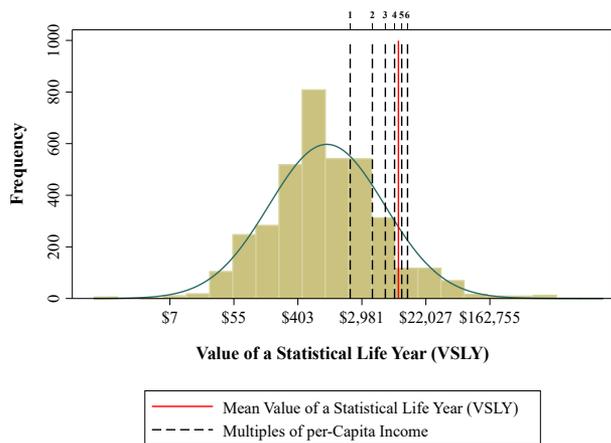| N = 3985	Mean or proportion	SD
Proportion female	0.72	0.45
Age	39.05	14.76
Proportion married	0.73	0.44
Proportion has children	0.81	0.4
Number of children	3.32	1.8
Perceived health (1-5)	3.59	0.75
Household food insecurity access category	2.15	1.29
Annual income (2015 international dollars)	2070	9449
Proportion with insurance	0.14	0.35

SD indicates standard deviation.

potential life expectancy. Respondents can also use individualized preferences over time to determine their desirable recurring payment. Such individualized discounting is novel in the stated-preference literature and allows us to avoid making assumptions about both individual life expectancy and individual time preferences. Because our WTP is the annualized value of a 2% risk reduction, our VSLY is reached by multiplying this elicited WTP measurement by 50 to get to the annual value of a 100% point reduction in risk of death.[25,26] Owing to the lifetime recurring payment nature of the question, the value elicited is directly the total WTP for a 2% point risk reduction divided by individually perceived life expectancy. Therefore, when multiplied by 50, our value becomes not the VSL, which is the marginal rate of substitution between wealth and the risk of dying, but rather the marginal rate of substitution between wealth and the individual's perceived life expectancy, which is the VSLY.

In addition to establishing VSLY in this urban setting in SSA, we also compared it to the per-capita income in our sample. We used mean self-reported income from our survey as our estimate of local per-capita income. We elicited both WTP and local income in Tanzanian shillings (TZS) and converted it to purchasing power parity (PPP)-adjusted 2015 international dollars using the PPP-adjusted conversion factor of $1.00 = 721.5 TZS.[27,28] Our VSLY thresholds are computed using only elicited WTP and not computed using the full-income approach, where the value of the mortality risk reductions are added to the change in GDP or elicited income.[29] Finally, because our population is poorer than the Tanzanian GDP per capita, we used local mean income instead of national GDP per capita as the appropriate proxy for community-relevant income thresholds for our population.

Results

Demographics

Table 1 presents some of the key socioeconomic and demographic information collected from our study sample. The average age of individuals in our sample was 39.05 years. In addition, 72% of our sample was female, 73% of the sample was married, and 81% had children with the mean number of children being 3.32. Mean perceived self-assessed health was 3.59 of 5, and 14% of respondents had health insurance. Household food insecurity access category was 2.15 on average, which falls into the mildly food insecure range.[23] Finally, elicited per-capita annual income from our population was $2070 in 2015 international dollars, or about 78% of 2015 PPP-adjusted Tanzanian per-capita GDP ($2645).

Fig. 1 – Distribution of elicited value of a statistical life-year (VSLY) with multiples of local per-capita income.

Notes: Value of a Statistical Life Year (VSLY) as measured in our survey is reported in 2015 purchasing power parity (PPP)-adjusted international dollars. The income and VSLY in our survey followed a lognormal distribution so the scale of our x-axis has been log-transformed for ease of visualization and to better reflect the underlying normal distribution. The multiples of per-capita income are derived from multiples of our sample's mean elicited annual income of $2070 in 2015 international $.

Value of a Statistical Life-Year

The mean WTP for a 2% risk reduction in the probability of death over a given year was $187 (95% CI $124-$249). This value is equivalent to a mean VSLY of $9340 (95% CI $6206-$12 373). We employed *t* tests of our estimated VSLY compared with multiples of local per-capita annual income. The results suggest that elicited VSLY is significantly greater than 3 times the local per-capita income (*P* value: .025), allowing us to statistically reject the WHO-recommended VSLY threshold of 3 times per capita income. Empirically, we find VSLY to be approximately equivalent to 4.5 times local per-capita income. The underlying data of the log VSLY compared with various multiples of local per-capita income are displayed in Figure 1.

Relationships Between Individual Characteristics and VSLY

To demonstrate that our VSLY is consistent with economic theory and that income increases as VSLY increases, we present the results from a linear regression of VSLY on household income within our sample. We also include controls for age, sex, marital status, and self-reported health to demonstrate the robustness of our relationship to the inclusion of individual-level characteristics. Our results, presented in Table 2, demonstrate a strong positive relationship between VSLY and income, which is consistent with economic theory and serves as a validation of our survey results. Specifically, we find that a $1 increase in annual household income is associated with a $0.81 increase in VSLY (95% CI .48-1.14), regardless of whether other measured controls such as age, sex, marital status, or self-reported current health are included in the model. Although this model is certainly incomplete in describing all of the potential predictors of VSLY, we are fairly confident that the coefficient on income reflects the underlying relationship between wealth and the monetary value placed on healthy life-years within our sample, owing to income's insensitivity to the inclusion of all theoretically relevant measured covariates.

Discussion

Through our methodology, we have responded to the numerous calls for an empirically derived and setting-specific VSLY for a

Table 2 – The relationship between VSLY and income.		
Variables	**(1)**	**(2)**
	Without controls	**With controls**
Income	0.81[*]	0.81[*,‡]
	(0.48-1.15)	(0.45 1.16)
Age		−7381
		(−17 341 to 2580)
Sex		−168.6[‡]
		(−363.8 to 26.61)
Marital status		−7593[‡]
		(−15 279 to 92.59)
Self-reported health		961.2
		(−1378 to 3300)
Observations	3985	3905
R-squared	0.006	0.010

Note. Linear ordinary least-square regression results are presented. The outcome is VSLY measured in PPP-adjusted 2015 international dollars. Income is individual income elicited from our survey and converted into PPP-adjusted 2015 international dollars. Age is in years, sex is a binary indicator for female, and marital status is a binary indicator for being currently married. Self-reported health is measured on a 1-5 Likert Scale with 5 being the highest health status and 1 being the lowest health status. Robust 95% CIs are presented in parentheses.
PPP indicates purchasing power parity; VSLY, value of a statistical life-year.
[*] *P* < .01.
[†] *P* < .05.
[‡] *P* < .1.

community in SSA.[4-6,8] In multiples of per-capita income, this empirical value is 50% higher than the WHO-recommended multiple (4.5 instead of 3.0 times). Because the vast majority of all cost-effectiveness studies done in SSA use the WHO-recommended thresholds, our results suggest that a significant number of cost-effective investments may have been ignored.[4-6] The VSLY as assessed in the United States has ranged from $100 000 to $500 000 (1990 USD).[30] Because the US GDP per capita in 1990 was $23 954, this puts the VSLY between 4 and 20 times per-capita GDP.[30] In the European Union, median VSLY was assessed to be a median of €158 448 with upper and lower bounds at €117 956 and €231 442 (2014 Euros). Because the per-capita GDP of the European Union in 2014 was approximately €27 000 (2014 Euros), this puts VSLY at between 4.3 and 8.5 times per-capita GDP with a median of 5.8 times per-capita GDP.[31] Although numerically lower in absolute terms, our derived VSLY for our setting in Tanzania is similar relative to per-capita income as the lower bound ratio from the United States and the European Union. Because our population is poorer on average than Tanzania as a whole, this could imply that the national VSLY ratio for Tanzania is higher, in line with the range of findings from the United States and the European Union.[30,31]

Our study has several strengths in computing VSLY through contingent valuation. The first is that we measured VSLY empirically from the population of concern without having to back out risk from reveled preferences or make complicated assumptions about discount rates, life expectancies, risk knowledge, or choice sets as required by other approaches. Second, the ability to obtain local income directly from the same population as the VSLY allowed us to relate the VSLY estimates to actual earnings, rather than to aggregate national income proxies that may not apply to the particular population of interest. The VSLY estimates need to

be compared to estimates of local income to ensure the positive relationship between VSLY and income that is necessitated by economic theory holds true.[32] In fact, as expected, we find a strongly significant positive relationship between income and VSLY in our data, which indirectly validates our results. A final strength of our study is that it was carried out within an established HDSS where surveyors have a historically close relationship with the local community. This setting facilitated our intensive pilot study, which greatly improved the applicability of our survey instruments to the local context. As a result, over 90% of participants in the final survey attained the highest level of surveyor-assessed comprehension of the VSLY scenario.

Although our study has several strengths, it also has several limitations. First, individuals may provide results that are not reflective of their actual preferences. This may be due to a desire to appear a certain way in front of the reviewers or to protest the placing of a dollar value on life. Such issues are common when comparing results of self-assessments and stated preferences to those obtained through revealed preferences. Although we are unable to compare these stated preferences to any revealed-preference data among similar populations in SSA, we do examine the potential for response abnormalities such as protest zeros, which would indicate that the elicited monetary values are not reflective of true values. Protest zeros typically occur when participants reject a VSLY elicitation question because they expect others, such as government, to fund the interventions that they are asked to pay for hypothetically.[33] Protest zeros may have placed a downward bias on our results by eliciting a zero value of VSLY when, in fact, the individuals do place a non-zero value on life. Our data indicate that 246 individuals, or approximately 6% of our sample, gave a zero value for WTP. When exploring whether these values could be protest zeros, we examined the mean self-reported income of this group compared with the study sample mean. The mean self-reported income for those who reported a zero value for WTP was $901 PPP-adjusted 2015 international dollars per year, or approximately 56% lower than the average income recorded in the sample. As such, these individuals are significantly poorer than the average individual in our sample and may genuinely not be able to afford to pay anything for such a small risk reduction as presented in our questionnaire.

Another limitation is that our sample is only representative of 1 peri-urban community in Tanzania, and the generalizability to other settings in SSA may be limited. For the study community and for similar communities in East Africa, our VSLY is likely valid. Nevertheless, our process of eliciting and expressing the VSLY threshold for cost-effectiveness in per-capita income instead of per-capita GDP already provides a robust methodological approach, which is transferable to other settings, even if the specific value derived is not directly generalizable. For instance, we know that the per-capita income in our study community is 22% lower than the national per-capita GDP for Tanzania. Using this information, we can easily adjust our empirical VSLY threshold to account for the higher ability to pay at the national level. This is due to our empirical evaluation of the relationship between VSLY and income in our sample.

Other limitations to our approach are behavioral and involve the process of elicitation. The first involves the interpretation of the payment card scenario and the potential for anchoring responses to the values depicted on the card.[34] We attempted to mitigate this concern by allowing individuals to state values between amounts listed in the card. Approximately one-third (28.7%) of all respondents chose a value that was between values included on the payment card. This non-trivial amount of in-between results provides some credibility to the idea that the payment card did not yield excessive anchoring to the listed values.

A second potential behavioral limitation is due to the difference in wording for those who did not demonstrate adequate understanding of the risks presented in the initial scenario and needed the scenario re-explained in terms of community members. There is some evidence in the literature that these 2 phrasings may elicit different values owing to the self-versus-other perspective of the explanation.[35,36] This may be due in part to that individuals may not be able to differentiate hypothetically between their own community on a personal or emotional level with a community that is identical to theirs in objective characteristics only (eg, income, age distribution, geography). Although this limitation of perception is valid, only 171 of 3985 (4.2%) individuals surveyed required rephrasing to elicit high understanding, and the results do not change significantly if these individuals are excluded (P value: .986). As such, we expect the potential impact of social preferences and hypothetical bias on elicited values to be minimal.

Finally, our study only examined the demand side for health investments. Inherently, the ability to invest in health up to what is optimal on the demand side will be constrained by what is operationally efficient on the supply side.[37-39] We recommend that, in practice, these demand-side threshold values be taken into consideration with additional supply-side information, particularly regarding the political economy of the health system, the efficiency and quality of service delivery, and the fiscal space for investment in health. These supply-side characteristics will help to shed light on the systemic opportunity costs associated with public investments in health, which may be different than the opportunity costs implicit in the individual's derived valuation.

Conclusion

Our study has generated the first survey-based VSL and VSLY estimates for a community in SSA. The findings of this study also demonstrate that the WHO-recommended 3 times per-capita income threshold is an inappropriate cutoff to distinguish between health interventions that are cost-effective as opposed to not cost-effective, even in a setting that is 20% poorer than the national average. Because we find that a value of 4 to 5 times per-capita income would more accurately reflect the true value placed on a statistical life-year in our community, using a 3-times-per-capita income cutoff would lead to an underinvestment in cost-effective health interventions. Our study also establishes a survey methodology that can be adopted in other communities within Tanzania or throughout SSA to generate community-specific cost-effectiveness thresholds. Finally, our results contribute to a nascent body of VSLY estimates in developing settings, which are needed to ensure that recommendations regarding the cost-effectiveness of health interventions accurately reflect the value placed on them by the target population.

Acknowledgments

Supplemental Material

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.vhri.2019.07.009.

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