Value of Life and Measuring the Benefits of Landmine Clearance in Cambodia

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Abstract

This paper presents estimates of the benefits of clearing landmines in two provinces in rural Cambodia using the contingent-valuation (CV) method. The data came from a survey where we asked respondents referendum-type questions that elicit their willingness to pay for landmine clearance. The survey also provides estimates of the injury risk-death risk trade-off and the implicit value of statistical injury. These estimates suggest that the value of lives and injuries saved from mine clearing is likely to be at least an order of magnitude greater than those used in existing studies of mine clearing. We show that the value of lives and injuries saved is likely to dominate benefit assessments when VSL estimates are used. Estimates previously obtained for rural Thailand are contrasted with the results for Cambodia, and the determinants of the VSL investigated using econometric techniques. While Harris (2000) found a significantly negative net present value of landmine clearance in Cambodia we show that when using VSL estimates the net present value is less negative, and the value of lives and injuries saved dominates the benefits.

JEL: J17, J28, 022, Q28
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1. Introduction

Landmines and unexploded ordnance (UXO) are an important source of risk in rural areas of many countries. Every year they kill or injure almost 15,000 civilians in over 70 countries (ICBL, 2002: 40). They undermine the economy and food security of poor countries by making millions of hectares unavailable for growing food and herding livestock (Andersson *et al*. 1995). The feared presence of landmines stops refugees from returning to their homes, causing an on-going burden to host communities and aid agencies. Within mine-affected communities, the dangers are faced especially by the poorest people, who have to roam widely in search of water, fuel and forest foods, increasing the danger of entering unmarked minefields (Roberts and Williams, 1995). Landmines are particularly deadly for children, who have a higher fatality rate from stepping on mines because, being smaller, their vital organs are closer to the blast (Mathieson, 1997).

The world has responded to the risks posed by landmines and UXO by spending over US$1.5 billion on mine clearance since 1992. The overall trend is for spending to rise, with US$250 million spent on mine clearance in 2001. Yet most cost-benefit evaluations of landmine clearance suggest that it is socially inefficient. Harris (2000) estimates that expenditure to remove landmines from Cambodia would produce benefits – in the form of saved lives, reduced injuries and medical costs, and greater agricultural output – that are worth just two percent of the costs. In Mozambique, the benefits would be worth only ten percent of the costs (Elliot and Harris, 2001). For Bosnia and Herzegovina Paterson (2003) concludes that demining cannot be justified on development grounds.

Existing cost-benefit analyses of landmine clearance (Harris, 2000, 2002; Elliot and Harris, 2001; Patterson, 2003) have been constrained by inadequate data, which may have influenced the conclusions. These studies value injuries and premature death from landmines according to the present value of lost earnings (or lost GDP). This foregone earnings approach is no longer popular in developed countries because it ignores risk aversion and greatly underestimates the value of life (Rosen, 1988). Instead, researchers and policymakers now use estimates of the *Value of Statistical Life* (*VSL*), calculated from reports by survey respondents of how much they would be willing to pay to avoid risks or from market based, revealed preference studies. The theoretical superiority of broader measures of the value of life is recognised by Harris (2000), but because no estimates exist for countries with landmine problems the out-dated foregone earnings method was used. Perhaps as a result, saved lives and disabilities are a small part of the calculated benefit of landmine clearance, whereas the value of statistical life is easily the largest benefit of environmental, health and safety rules in the U.S. (Shogren and Stamland, 2002).

While economists may have been underestimating the value of lives saved from landmine clearance, mine clearance agencies may have been overestimating these values, causing them to spend excessive amounts on risk reduction. Most landmines are located in poor countries, but most landmine clearance is paid for by rich country donors and NGOs. Elliot and Harris (2001) suggest that donors may value the lives saved by clearing mines using standards from their own (rich) countries. This also may explain why the standards are so stringent, because the goal of accredited mine clearance agencies is to remove all mines (and unexploded bombs) in an area (UNMAS, 2003). This standard requires expensive manual inspection of almost every inch of ground because existing machines cannot find every single mine. In contrast, the socially efficient standard is to reduce the risk from landmines only to the point where the marginal cost per life saved is the same as for other risk reducing activities (Viscusi, 2000). Hence, in poorer countries, where people face many health risks, less stringent mine clearance standards might allow spending to be diverted to other priorities.

Without reliable estimates of the statistical value of life, any assessment of the benefits of mine clearance is uncertain. This makes it difficult to judge the social desirability of demining particular areas, and the efficient degree of clearance. More generally, mine clearing is one of many development projects or policy interventions, all of which will have different risk reduction and income generation characteristics. Thus, estimates of the relevant risk-income tradeoffs are necessary to judge the desirability of mine clearance relative to the other policy alternatives available.

The present paper represents an attempt to estimate the value of statistical life and injury using the contingent-valuation (CV) method. We focus on the willingness of the rural population in Cambodia to pay for the reduction in risk that would result from landmine clearance.

Cambodia has the highest rate of civilian landmine and unexploded ordnance casualties in the world. With over 46 percent of Cambodian villages still contaminated by landmines (CMAC 2002), landmine removal is vital to economic progress in Cambodia's rural areas. But with an estimated 4,500 square kilometres of Cambodian land thought to still be contaminated by landmines (CMAC 2002), Cambodia's limited clearance abilities are a serious hurdle to rural development. The Cambodian Mine Action Centre (CMAC), employing close to 3,000 deminers, has a current clearance capacity of only about 10-12km^2 per year.[1] The number of civilian landmine victims per year has not fallen significantly over the last 10 years of demining activity (CMAC 2002), suggesting that direct removal efforts are slow relative to the total size of the problem. In the twelve months from September 2003 to August 2004, 521 incidents were reported that involved unexploded ordinance and 353 incidents involving mines. Nineteen per cent of these accidents resulted in death (approximately 166 deaths) and 21 per cent amputations. The accidents were spread across most of Cambodia, with accidents reported in 22 or the 24 provinces. Over the affected provinces the accident rate is 9.6 per 100,000 people per year. In some provinces the accident rates are very high, e.g. Krong Pailin (616 per 100,000 per year), Otdar Mean Chey (174) Preah Vihear (34) and Battambang (27).

In addition to contributing to the literature that attempts to analyse the costs and benefits of landmine clearance, our study is also relevant to the broader literature on the value of risk reduction. A key requirement for any rational risk policy is some knowledge of the value to place on lives that are saved by interventions that aim to reduce risk. In contrast to the developed countries, almost nothing is known about the value of statistical life in developing countries. A recent survey of 70 estimates of VSL finds only four that come from countries that might once have been considered as developing (Taiwan and South Korea) and none from currently developing countries (Miller, 2000).

In order to illustrate the implications of the VSL measures obtained for cost-benefit studies of mine clearance, we reconsider the study by Harris (2000) of mine clearance in Cambodia. Harris

[1] To give an idea of the number of mines and UXO yet to be removed, from the total of 90+ square kilometres of land that it cleared of landmines/UXO from 1992-2001, CMAC found 148,820 anti-personnel mines, 2,930 anti-tank mines and 667,160 items of UXO (CMAC 2002).

estimated that a US$3,500m investment to clear 500,000 ha of arable land would have a net present value of –US$3,434m, with the value lives and injuries saved only 8.7% of the present value of benefits. While the use of plausible VSL measures that would follow from our study does not make the present value positive, the present value of benefits is shown to be a much larger proportion of costs. We also show that the value of lives and injuries saved is likely to dominate benefit assessments when VSL measures are used.

The outline of this paper is as follows. Section 2 briefly reviews existing estimates of value of lives saved and injuries reduced in studies of the benefits of mine clearance. The methodology used in the survey to determine risk-money tradeoffs and injury risk-death risk tradeoffs is described in Section 3. The results of the survey are outlined in Section 4 and determinants of the VSL estimates investigated. In Section 5 the results of the survey are compared with VSL estimates in the literature and possible biases are considered. A cost-benefit study by Harris (2000) is reconsidered using our VSL estimates in Section 6. Section 7 concludes the paper.

2. Previous Valuations of the Life Saving Benefits of Landmine Clearance

Table 1 summarises the ways in which lives saved as the result of landmine clearance have been valued in existing studies. All of these studies have treated the benefit resulting from the saving of lives as the present value of lifetime income foregone. However, it has long been recognised that income forgone or net income forgone, obtained by deducting some allowance for consumption, are inadequate as a basis for assessing the value of statistical lives saved. These measures fail to place value on life itself, the trauma of death, or the psychological affect of living in fear of premature death resulting from a particular risk.[2] Perhaps because of this, the value of lives saved is only a small proportion of the estimated benefits in existing studies of mine clearance.

There is now a substantial body of literature that addresses the value of risk to life and health. Contingent valuation or revealed preference methods have been used to estimate the VSL in a large number of countries and for a wide variety of risk.[3] Miller (2000) uses 68 studies, 38 outside the U.S., in his study of the relationship between the VSL and income. This study clearly shows that the values of statistical life obtained using contingent valuation or revealed preference methods are not close to estimates based on the present value of lifetime income foregone. For the world as a whole suggested VSL estimates are between 137 and 195 times GDP per capita, or approximately 14 to 20 times the present value of lifetime GDP per capita for a 40 year working life and 10% discount rate. The ratio of VSL measures to GDP per capita is likely to be higher for developing economies.

[2] For an excellent survey of early studies of the valuation of life and a critique of these studies see Jones-Lee (1976). Harris (2000), Harris (2002) and Eliot and Harris (2001) do not value the psychological costs associated with the risk of death.
[3] For a now dated, but useful review see Viscusi (1993). For a recent critical review of market based estimates see Viscusi and Aldy (2003).

Table 1: Value of Lives Saved in Previous Economic Evaluations of Landmine Clearance

Author (year)	Country	Valuation concept	Annual value [Lifetime PV][a]	Notes
Harris (2000)	Cambodia	GDP per capita	$134 [$1310]	NPV of -$3,434m on investment of $3,500m
Elliot and Harris (2001)	Mozambique	GNP per capita	$140 [$1370]	NPV of -$28m on $31.4m investment
Harris (2002)	Afghanistan	Average wage rate	$550 [$5,400]	NPV of $1,265m on investment of $100m
Patterson (2003)	Bosnia-Herzegovina	Annual labour income	$2,065 [$20,200]	n.a.

Notes: All present values are calculated at 10% discount rate.
[a] Based on a 40 year working life.

In earlier work on the value of landmine risk reduction in rural Northeast Thailand, Tressler et al (2004) estimated the value of statistical life at between US$0.2-0.3 million. Transplanting this value into the cost-benefit analysis undertaken by Harris (2000) would still yield a large negative net present value of investment. However, the value of lives saved would now dominate the benefit assessment[4].

3. The Survey

3.1 Outline of the Approach

A contingent valuation survey was carried out by the authors in Kampong Speu and Siem Reap provinces in November 2004, with the assistance of Cambodian Red Cross and a team of local interviewers. This survey represented a significant extension and revision of the approach adopted in and earlier survey in rural Northeast Thailand (Tressler et al, 2004). In contrast with that earlier work, the two provinces surveyed here are affected by landmines (Siem Reap) or UXO (Kampong Speu). The accident rate in Siem Reap is 3.4 per 100,000 people per year, while in Kampong Speu it is 1.3 per 100,000 people per year.

The general methodology chosen for the survey was based on that used by Viscusi *et al* (1991) in studying chronic bronchitis and auto fatality risk in the U.S. Perreira and Sloan (2002) have also used this approach in considering disability and death risks in the U.S. The survey design and its application were adapted to enable this approach to be applied in low income rural communities, and to address the issues of concern in this study. Experience gained from the earlier Thai research allowed this survey to be further tailored to improve understanding among rural respondents with relatively low education levels.

[4] Depending on the income elasticity of VSL used, the NPV varied from -$3,202.5 million (elasticity of 1) to $2,321.9 million (elasticity of zero) and saved lives as a percentage of benefits varied from 79.7 to 94.9 per cent, compared with 8.7 per cent in Harris' (2000) original assessment.

The core of the survey used two series of questions to determine tradeoffs between alternatives. The first of these related to the tradeoff between decreases (increases) in the risk of death resulting from landmine accidents and income, i.e. a "risk-money" tradeoff. A further set of questions was used to determine the tradeoff between the risk of injury from a landmine accident and the risk of death, a "risk-risk" tradeoff. Viscusi *et al* (1991) also considered chronic bronchitis risk-dollar tradeoffs. We did not consider injury risk-money tradeoffs, although these tradeoffs can be determined indirectly from the results of the survey.

The risk-money and risk-risk tradeoffs were determined by asking respondents to state their preferences for two different communes in which they might live. For the risk-money tradeoffs the areas differed by the risk of death and cash income. For the risk-risk tradeoffs the areas differed by the risk of injury and the risk of death. Thus, in determining risk-money tradeoffs the respondents were not directly asked about their willingness to pay for a reduction in risk, or the amount required to accept an increase in risk. This approach makes it possible to avoid issues associated with who will or should pay, how payments will be made, and exactly what the payments are for. These types of issues would be important for the communities involved in this survey, particularly when you consider that the majority of landmine clearance in Cambodia is conducted by local non-government organisations supported by international donor programs.

The statement of alternatives also made clear the precise nature of the change in risk to be considered. This is important because it is likely that in communities with significant experience with landmine problems risk comparisons may be influenced by actual perceptions of landmine accident risk. The survey also collected information that could be used to determine the respondents' actual perceptions of landmine risk for themselves and for their commune.

Although the survey did not directly ask respondents for their willingness to pay to reduce risk or willingness to accept risk, the way in which the alternatives were presented could be interpreted in these terms. Viscusi *et al* (1991) note the possibility that the way in which the alternatives are presented may affect results, since risk increases may be valued differently from risk decreases. In low income rural communities these differences could be particularly pronounced. Earlier research in Thailand compared results of a "willingness to pay" with a "willingness to accept" format for studying landmine risk reduction (Tressler et al, 2004). The decision to use the "willingness to accept" format in this survey was based on the Thai survey, where the differences between results using the two formats was very small and statistically insignificant, and the results from the "willingness to accept" format appeared to be more informative. Also, using the "willingness to accept" format avoided presenting alternatives that look significantly worse than the respondents' current village, at least in terms of cash income, and therefore avoided potential confusion where respondents would prefer neither alternative.

The results of the survey enable us to address the following questions for Cambodia:

1. What is the distribution of landmine death risk-money tradeoffs?
2. What is the distribution of landmine injury risk-death risk tradeoffs?
3. What is the implicit distribution of landmine injury risk-money tradeoffs?
4. Do actual perceptions of landmine risk affect the distributions of tradeoffs?
5. What demographic and economic variables influence the value of statistical life?

3.2 Methodology

There is now a substantial body of literature that notes the sensitivity of VSL estimates based on CV methods to the nature of the risks considered, the way in which risks are presented, the size of the risk change and many other factors.[5] In low income rural communities these factors are likely to be even more significant. Particular concerns with survey approaches to health risk are limitations on the ability of individuals to understand the evaluation tasks that they are presented with, and to interpret the risk information that is presented (Viscusi, 1993). In this study risks were not presented in terms of annual probabilities of death or injury, but in terms of the frequency of occurrence of an event, e.g. a change in the risk of death from 4 per year in a population of 10,000 to 2 per year. In an attempt to further simplify the statement of risk, respondents were asked to consider a commune containing 20 villages each with 500 inhabitants and a particular number of deaths or injuries across the villages each year.[6] Showcards were also used to explain and compare risks.[7]

Viscusi *et al* (1991) and Perreira and Sloan (2002) use cost of living differences to represent the money component of risk-money tradeoffs. In low income rural communities subsistence agriculture provides a substantial proportion of income, and there is no housing market for ownership or rental that is similar to markets in high income economies. Thus, the cost of living concept is both difficult to explain and hard for the respondents to interpret. In this survey cash income and the change in cash income between areas was used to represent the money component of risk-money tradeoffs.[8]

To check comprehension the respondents were initially asked for their preference between alternatives in which one area was dominant, since it had a higher cash income level and lower probability of death, or lower probabilities of both death and injury in risk-risk comparisons. If a respondent failed to select the dominant area the nature of the risk and the selection task was explained again. The interview was terminated if the respondent failed on a second attempt.[9]

Landmine accidents cause a variety of injuries of different severity, including loss of legs, feet, arms, hands and sight. The loss of a leg, either above or below the knee, is the most common serious injury sustained. In this survey the respondents were asked to treat all injuries as involving a loss of a leg below the knee. Clearly, different injuries would generally be associated with different tradeoffs.

Respondents were initially asked a set of questions designed to determine their experience of landmines, including whether they had ever been a soldier or militia, their awareness of landmine affected areas, their travel time distance from these areas, and knowledge and association with those injured or killed by landmines. Familiarity with landmines and landmine accidents is likely

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[5] See for example Beattie *et al* (1998) who show that significant anomalies may remain even when respondents are given the opportunity to discuss issues relating to the survey and have the ability to revise initial responses.

[6] This would be a reasonable village size in mine affected communities in Cambodia. This differs slightly from the earlier survey in Thailand, where participants considered 10 villages of 1,000 inhabitants.

[7] An example of a show card used is provided in Figure 2.

[8] Since respondents were asked to state preferences for alternatives that involved cash incomes that were generally different from their own, this approach changes the interpretation of any analysis of the relationship between income or expenditure and estimates of VSL.

[9] Overall, three respondents failed the dominance tests and the responses were excluded from analysis.

to influence preferences, and thus the VSL estimates and risk-risk tradeoffs. To help respondents think about their current income levels respondents were asked about their family's household domestic expenditure. Demographic variables and wealth indicators were also collected from each respondent.

Studies in the U.S. such as Viscusi *et al* (1991) and Perreira and Sloan (2002) have been able to use multimedia tools to explain the risks and tasks involved, and interactive computer programmes in administering questionnaires. This study was based on personal interviews. Interviewer teams with significant local experience in household interviews were recruited and trained to explain the nature of risks involved and the tasks required of the respondents.

3.3 Risk-Money Tradeoffs

The first set of questions in the core of the survey was designed to determine for each respondent the value of income that would make Commune One and Commune Two indifferent given a specified difference in the risk of death from a landmine accident. This then enables the VSL to be calculated. Following Viscusi *et al* (1991), assume that risk preferences can be represented by the utility function $U(H,Y)$ if the individual is healthy or $U(D,Y)$ if death occurs from a land mine accident, where Y is total income. Let I_a and I_b be the cash income levels in Communes One and Two and W be the common value of income from other sources (in our case this would include income from subsistence sources). The probabilities of death in Communes One and Two are X_a and X_b respectively. Indifference between the two areas implies that

$$X_a U(D,W+I_a)+(1-X_a)U(H,W+I_a)=X_b U(D,W+I_b)+(1-X_b)U(H,W+I_b). \qquad (1)$$

As in Viscusi *et al* (1991), if the utility function is additively separable in health status and income, and the marginal utility of income is constant and equal to one for the range of income changes considered, then

$$u(D)=u(H)-L, \qquad (2)$$

where

$$L=\frac{I_a-I_b}{X_a-X_b}, \qquad (3)$$

and $u(.)$ is the utility function for health status.[10] For example, if I_a=R1,460,000, I_b=R1,660,000, X_a=0.0004 and X_b=0.0002, then L=R1,000,000,000 or $u(H)=u(D)$+R1,000,000,000.[11]

In order to determine the income difference that would make Commune One indifferent to Commune Two for a given change in the risk of death a respondent was presented with an initial

[10] In Viscusi *et al* (1991) I_a-I_b=Z, the difference in the cost of living between Area A and Area B.

[11] This would correspond to a VSL of US$259,699 using the average exchange rate over the period during which the survey was undertaken of 3850.607 Riel per US dollar.

alternative that was then adjusted given the area that was preferred.[12] The initial alternatives were selected after a pre-test involving several villages in Kampong Speu province. Such pre-testing reduces the likelihood of starting point bias and minimises the number of iterations required to establish indifference.

The initial alternatives used in the final survey were:

Commune One	**Commune Two**
Cash Income of R1,460,000 per year Risk of Death per year of 2/10,000	Additional Cash Income of R200,000 per year Risk of Death per year of 4/10,000

If Commune Two was selected as the preferred area, the additional cash income in Commune Two was revised down by R50,000 and the respondent was asked to reconsider the alternatives. This process was continued through a series of up to four iterations until preference switched to Commune One or the additional cash income in Commune Two reached zero. Any switch in preference provides a range within which the income level that would make the areas indifferent should lie. The respondent was then asked what level of additional cash income in Commune Two would make the areas equally desirable. If this value was inconsistent with the range of incomes implied by the preference switch, then interviewers prompted the respondent for a suitable response. If the respondent still gave an inconsistent value, then this survey response was disregarded. This process provided an additional consistency check.[13] If Commune One was selected given the initial alternatives, the additional cash income in Commune Two was revised upward by R50,000 through a series of up to four iterations until Commune Two was selected or the level of additional cash income had reached R400,000. Again, the respondent was asked for the value of additional cash income in Commune Two that would make the areas equally desirable. This questionnaire design is said to have a "willingness to accept" format since the income that was revised was that in Commune Two which had a higher risk of death, although clearly the respondent could have chosen decreased risk and lower income by selecting Commune One on any iteration.

The use of cash income in this survey presented a particular challenge. The first pre-test of the survey involved asking respondents to choose between two areas with differences in daily cash income. It appears that given this format the respondents were subconsciously comparing the daily cash incomes in both alternatives with the cash income they could obtain in the local day labour market. Obviously the local day labour market offers higher wage income since the daily incomes used in the survey were to represent 'average' daily incomes. Second, since the differences in risk considered were very small, the differences in a daily cash income between the two areas changed very little between iterations[14]. In contrast, rural villagers do not commonly think of yearly amounts of cash income or expenditure, and thus could not easily compare two amounts of yearly cash income. To overcome this, in the final survey cash income

[12] Respondents were asked to assume that all other aspects of the areas considered were similar except for the cash income levels they would earn and the risk of death, and that these other aspects of the areas were similar to the present location in which they lived.
[13] No responses were disregarded as a result of failing the consistency checks.
[14] For instance, the change in additional income between R200,000 per year (R547 per day) and R150,000 per year (R411 per day) is only slightly bigger than the smallest denomination of currency used in Cambodia (R100).

in Commune Two was described as the income in Commune One plus an additional amount of income representing the income difference.[15]

Pre-testing of the survey established that, for the difference of risk of 2/10,000 between Communes One and Two, an appropriate starting cash income differential of R200,000 per year should be used.

3.3 Risk-Risk Tradeoffs

The second set of questions was designed to determine the willingness of respondents to tradeoff the risk of injury from a landmine accident for increases in the risk of death from a landmine accident, or for a given population the tradeoff between injury and death. Given two alternative Communes One and Two, the questions sought to find the risk combination that would make Commune One indifferent to Commune Two, assuming that all other aspects of the communes are identical. Following Viscusi *et al* (1991), consider a state-dependent utility model where $u(D)$ is the utility associated with death from a landmine accident, $u(J)$ the utility of living with an injury, and $u(H)$ the utility associated with full health.[16] Let X_a and Y_a be the annual probabilities of death and injury in Commune One and X_b and Y_b be the corresponding probabilities in Commune Two. Given indifference between Commune One and Commune Two

$$Y_a u(J) + X_a u(D) + (1 - Y_a - X_a) u(H) = Y_b u(J) + X_b u(D) + (1 - Y_b - X_b) u(H). \quad (4)$$

It follows that

$$u(D) = tu(J) + (1-t)u(H) = u(H) - t(u(H) - u(J)), \quad (5)$$

where

$$t = \frac{Y_a - Y_b}{X_b - X_a}. \quad (6)$$

The tradeoff between injury and death is defined as t. For example, if for Commune One Y_a = 0.002 and X_a = 0.0002 while for Commune Two Y_b=0.0012 and X_b=0.0004, then indifference between the areas would imply an injury-death tradeoff of 4.0.[17]

The procedure used to determine the risk-risk alternatives that made Commune One and Commune Two indifferent for the respondent was based on the same procedure as used for risk-money choices. The initial alternatives used were[18]:

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[15] In the Thai survey, difference in yearly cash income between the two areas was used.
[16] These utilities can be treated as those derived from the two variable utility function used above under the assumption of additive separability. For risk-risk comparison the values of total income in the two areas are identical.
[17] The tradeoff ratio in Viscusi *et al* is the death-injury tradeoff $1/t$.
[18] Note these are the same initial alternatives used in the earlier Thai study (Tressler et al, 2004).

Commune One	**Commune Two**
Risk of Injury per year of 20/10,000	Risk of Injury per year of 12/10,000
Risk of Death per year of 2/10,000	Risk of Death per year of 4/10,000

If Commune One was chosen the number of injuries per 10,000 in Commune Two was revised down until preference switched or there were zero injuries.[19] The respondent was then asked what number of injuries per 10,000 would make the areas indifferent. As above, this provided a consistency check. If Commune Two was chosen the number of injuries per 10,000 in Commune Two was revised up in a similar way until preference switched or the number of injuries reached twenty.

3.4 Implicit Value of Statistical Injury

The estimates obtained for the value of statistical life, L, and the injury risk-death risk tradeoff enable the implicit value of a statistical injury to be calculated. From (2) and (5) it follows that

$$u(H) - L = tu(J) + (1-t)u(H), \text{ or}$$

$$u(H) - u(J) = \frac{L}{t}. \qquad (6)$$

3.5 Application of the Survey and Sample Characteristics

An experienced team of Cambodian interviewers were recruited locally and trained in the survey methodology and use of the survey instrument. Recruitment of local interviewers ensured that interpretations and language used for the survey were consistent with those in use in the survey area.

The villages selected for the survey were identified from the Cambodian Socio-Economic Survey (CSES). Seven villages were selected from Kampong Speu province, and ten villages from Siem Reap province. Of these villages, two from Kampong Speu were used in pre-testing and did not form part of the final sample. A sample of up to sixty households was randomly selected from each village for interview. One individual (or occasionally two) from each household was interviewed. Participation in the survey was voluntary, but the refusal rate was zero. This provided an overall sample of 497 responses from fifteen villages in the two provinces. Three responses were excluded for failing either the dominance tests, or the consistency checks, resulting in 494 usable responses.

[19] To reduce the number or iterations the last step involved a decrease of 4 injuries per 10,000.

Table 2: Sample Characteristics and Consistency Checks

	Cambodia	Thailand (Tressler et al, 2004)
Number of respondents	494	311
Had lived in landmine-affected village	288 (58.3%)	4 (1.3%)
Had been a soldier or militia	303 (61.3%)	N/A
Knew somebody killed or injured by landmines	413 (83.6%)	8 (2.6%)
Had cared for somebody injured by landmines	293 (59.3%)	0 (0.0%)
Knew of a village affected by landmines	318 (64.4%)	62 (19.9%)
Number Failing Consistency Checks	3	15

Table 2 provides a summary of the sample characteristics and consistency checks for responses from the survey. As the table makes clear, in contrast with the earlier Thai study, most respondents in Cambodia had significant personal knowledge of the effects of landmines and the location of landmine-affected areas. For those who knew of a landmine affected area, these areas were an average of 49 minutes travelling time away, compared with six hours for Thailand. Over half of respondents had experience caring for someone injured by a mine, compared with none in Thailand. Only three of the survey respondents failed the consistency checks, with all failures occurring in dealing with risk-money tradeoffs. Consistency failures may have resulted from misunderstanding or mistakes by the respondents, or coding errors by the interviewers. The greater experience of the interviewers in this survey, and greater care in explaining the alternatives to respondents, probably accounts for the difference between the two surveys in the number of respondents failing consistency checks.

4. Results

4.1 Risk-Money Tradeoffs and the VSL Estimates

To simplify comparisons with other studies all VSL estimates are converted to $US using the average exchange rate over the period during which the survey was undertaken.[20] In all instances the midpoint between alternatives was used rather than the survey response obtained by prompting. The obvious exception to this was where the respondent initially chose Commune One (the low risk commune) in the risk-income tradeoff, and did not switch within four iterations. In that case, the prompted indifference value was used. The “willingness to accept” format provides the opportunity for the respondent to never switch between the two Communes. In this case, their value of statistical life would be calculated as infinity. These responses are analysed separately.

[20] The average exchange rate over the period during which the survey was undertaken of 3850.607 Riel per US dollar. However the parallel exchange rate available in most markets, for instance, is 4000 Riel per US dollar. Using the parallel exchange rate would decrease all VSL and other estimates by 3.7%.

The first part of Table 3 below gives the means, weighted means, medians and standard deviations of the VSL estimates based on the indifference points estimated by the respondents[21]. Corresponding data from the earlier Thai survey conducted in 2004 is provided for comparison purposes.[22] When compared with the mean VSL from the earlier Thai survey, the mean of $443,172 seems very high, particularly when you consider that Cambodia has much lower per capita income. This may be explained by the much higher personal experience of landmines and landmine accidents for Cambodian respondents. For 2003, the value of income per capita in Cambodia was In 2001 the value of income per capita in Cambodia as a whole was approximately $270.[23] For a 40 year working life and a discount rate of 10% the present value of forgone lifetime earnings would equal $2,640, thus the ratio of the VSL using the weighted means to lifetime earnings is around 168 to one. For Thailand, this ratio was around 37 to one.

The results suggest that the VSL varies significantly between respondents. The second part of the table provides the distribution of the income tradeoffs for a change in the risk of death from a landmine accident of 2/10,000, and the associated VSL. This distribution is based on the values of income at which there was a switch in preferences between areas. Again it will be noticed that there is significant variation in VSL estimates across the respondents in the survey.

Table 3: Risk – Money Tradeoffs and Value of Statistical Life Estimates

	Cambodia	Thailand (Tressler et al, 2004)
Mean VSL ($US)	443,174	304,425
Median VSL ($US)	422,011	344,778
Standard Deviation	383,207	104,475
Sample Size	494	157
% Not accepting regardless of income difference	10.3	0.0
% Selecting the low risk area initially	61.7	80.3

Distribution-Preference Change

Income Diff. for a Risk Change of 2/10,000 (Riel)	VSL Estimate ($US)	No.	%
≤0	≤0	3	0.6
R25,000	$32,462	36	7.3
R75,000	$97,387	23	4.7
R125,000	$162,312	29	5.9
R175,000	$227,237	19	3.8
R225,000	$292,162	27	5.5
R275,000	$357,087	65	13.2
R325,000	$422,011	95	19.2
R375,000	$486,936	79	16.0
≥R375,000	≥$486,936	67	13.6
Undefined	Undefined	51	10.3

[21] Summary statistics are computed excluding those responses where the VSL would be infinity.
[22] Thai data here is limited to that obtained using the "willingness to accept" format.
[23] Data obtained from the World Bank.

Regression analysis revealed that the characteristics of the respondents had some influence on their estimate of the VSL, and the direction of influence was consistent with theoretical expectations. Initial regressions were run on survey data against a dummy variable for the province; sex, age, and education (in years) of the respondent; a dummy variable indicating whether the respondent had any prior knowledge of landmines or landmine-affected areas; a dummy variable indicating whether the respondent had ever been a solider or militia; household size (in terms of number of people); and self-reported house value (as an indicator of wealth). In the reported regression, only the provincial dummy variable was excluded as insignificant. Regression results are reported in Table 4 below.

Table 4: Regression results

	Coefficient	p-value
Intercept	478549.5	0.000
Sex (F=1)	59681.4	0.164
Age	-2499.6	0.127
Education (years)	11210.4	0.080
Household size	-13307.0	0.126
House Value	0.00661	0.004
Soldier or Militia dummy	53376.7	0.202
Knowledge dummy	13780.7	0.780

While few of the explanatory variables are significant even at the 10 per cent level, it is interesting to note that the signs of all coefficients are consistent with what we would expect, with the possible exception of the positive coefficient for the gender variable. Older age reduces VSL estimate, as does a larger household size. Education, household wealth (as measured by self-reported house value), having been a soldier or militia, or otherwise having known someone who has been killed or injured by landmines, all increase the VSL estimate.

Table 5: Injury Risk-Death Risk Tradeoff

	Cambodia	Thailand (Tressler et al, 2004)
Mean	4.63	3.89
Median	4.50	2.5
Standard Deviation	2.52	2.98
Sample Size	494	311
% Not accepting regardless of risk difference	11.9	0.0
% Selecting the high death risk area initially	30.5	63.9

Distribution-Preference Change

Injuries per Death	No.	%
0	22	4.5
1	36	7.3
2.5	70	14.2
3.5	107	21.7
4.5	80	16.2
5.5	29	5.9
6.5	28	5.7
7.5	50	10.1
8.5	58	11.7
9.5	14	2.8

4.2 Injury Risk-Death Risk Tradeoffs

Table 5 provides summary statistics and the distribution for the tradeoffs between the risk of injury from a landmine accident and the risk of death. As noted above, injury here refers to an accident that results in the amputation of a leg below the knee. The summary statistics are based on the indifference estimate provided by the respondents, while the distribution statistics show the tradeoff based on the shift in preference between the areas. While 63.9% of the respondents indicated a tradeoff of less than five injuries per death, there were a number of respondents with a significantly higher tradeoff.

Approximately 4.5% of the respondents choose a tradeoff ratio of less than one, implying a preference for death over injury. These responses could represent genuine preferences for death rather than injury in low-income rural communities for respondents who view an amputee as having a particularly poor quality of life or as a burden to their family.[24]

[24] Viscusi et al (1991, p.45) report a similar result involving the risk of chronic bronchitis compared with the risk an auto fatality. They suggest that this could result from the treatment of auto risk as depending on driving habits, while the chronic bronchitis risk is largely involuntary. In this survey both injury and death result from mine accidents. These accidents could be viewed as either voluntary or involuntary accidents.

Table 6: Implicit Value of Statistical Injury

	Cambodia		Thailand (Tressler et al, 2004)	
Mean	$120,805		$211,114	
Median	$71,417		$123,135	
Standard Deviation	164,502		245,652	
Sample Size	443		157	
	No.	%	No.	%
0-$50,000	143	32.3	51	32.5
$50,000-$100,000	133	30.0	17	10.8
$100,000-$150,000	73	16.5	29	18.5
$150,000-$200,000	33	7.4	21	13.4
$200,000-$250,000	2	0.5	0	0.0
$250,000-$300,000	6	1.4	1	0.6
$300,000-$350,000	8	1.8	4	2.5
$350,000-$400,000	6	1.4	8	5.1
$400,000-$450,000	8	1.8	0	0.0
$450,000-$500,000	14	3.2	0	0.0
≥$500,000	9	2.0	25	15.9
Undefined	8	1.8	1	0.6

4.3 Implicit Value of Statistical Injury

As noted above, the VSL estimates and the risk-risk tradeoffs can be used to determine the implicit value of statistical injury. Table 6 above shows the values for both the Cambodian, and earlier Thai surveys. The mean of the Cambodian survey is much lower though the difference is not statistically significant due to the highly variable nature of the data. Both distributions are significantly right-skewed.

5. Discussion

5.1 Comparison with the literature

How plausible is the estimate of the VSL of US$0.4 million coming from the survey used here? The paucity of VSL estimates from developing countries makes comparisons difficult. We are aware of two studies of compensating wage differentials for risk of fatal and nonfatal injuries in India's manufacturing sector. Simon *et al.* (1999) estimate a VSL of US$0.15-$0.36 million, which is between 20 and 48 times foregone earnings. Shanmugam (2000) estimates a VSL of US$1.4 million, but once account is taken of self-selection bias the estimated VSL jumps to US$4.1 million Shanmugam (2001). This very high VSL for a developing country is 550 times the level of foregone earnings. Our results for Cambodia are in-between these two estimates, but probably more comparable to those of Simon *et al* for India. Average income levels in India are significantly higher than in Cambodia, at about US$800 per capita in year 2000.

Another comparison comes from Taiwan, where compensating wage differential estimates are available from the early 1980s (Liu, Hammitt and Liu, 1997). At that stage Taiwan might still have been considered a developing country, although even then the average income level was about US$5500 (in year 2000 dollars). The implied value of statistical life from that study averaged US$0.41 million (in 1990 dollars).[25] Given that incomes in Taiwan in the 1980s were about twenty times those in Cambodia now, this estimate also seems low in comparison with our results.

Contingent valuation estimates of the VSL for developing countries are rather harder to find. The only estimate that we are aware of is from Zhang and Zheng (2001) who value mortality risk reductions in Beijing. The VSL estimates from their 1999 survey range from US$0.06-$0.2 million, which is again lower than the estimate established for Cambodia.

Miller (2000) applies regression analysis to previous VSL studies in order to obtain estimates of the VSL for a number of countries. He suggests a best estimate for Thailand of $380,000 in 1995 US dollars, or around $450,000 in 2003 US dollars. While he does not estimate the VSL for Cambodia, we can infer from his estimate for Jamaica (which had a slightly higher per capita GDP than Cambodia) that VSL would be approximately $400,000 in 2003 US dollars This is consistent with the estimate we obtained.

5.2 Possible Sources of Bias in the Estimates

As noted above, VSL estimates based on CV methods have been shown to be sensitive to a variety of factors that may decrease the reliability of the results. In response Beattie *et al* (1998) add the subtitle "Caveat Investigator" to their investigation of scale, scope and framing effects. Here we briefly discuss three issues.

In the approach used in this survey to consider risk-money tradeoffs all respondents were presented with initial alternatives that involved a change in risk of 2 in 10,000 and an income change of R200,000, i.e. all respondents faced the same starting point. The importance of starting point bias has been noted in the literature, although empirical evidence is mixed (O'Brien and Viramontes, 1994 and Stalhammer, 1996). Perreira and Sloan (2002) use randomly selected initial values to avoid this bias. In this survey random starting points would have significantly increased the complexity of the survey for interviewers, and added to the iterations necessary to find indifference. As shown in Table 3, 61% of respondents chose the low risk alternative initially. This suggests that, despite adjustments made as a result of pre-testing, the initial change in income may still have been set too low. It is possible that a higher initial value may have resulted in higher VSL estimates. It will be desirable to test for starting point bias, and the data obtained in this survey will allow this testing to be done in future papers.

The theoretical framework on which the VSL estimates are based implies that the subutility function defined over final income is the same in the healthy state as when the individual anticipates death. In a study using data from the chemical industry Viscusi and Evans (1990) find the marginal utility of income given serious injury is less than when healthy, while Perreira and Sloan (2002) find no significant difference in a study of disability risk. If it is assumed that the individual anticipates no additional utility from income if death occurs, then back-of-the-

[25] Unlike the results of Shanmugam, the correction for selectivity bias in this study reduced the VSL by about 10 percent, so the uncorrected VSL was US$0.46 million.

envelope calculations using linear, logarithmic and square root utility functions for the utility of income when healthy suggest that the VSL would be no more than 6% less.

If the VSL measured as *L* represents the value of statistical life for small risk changes, then provided the change in risk remains "small" the required change in income to compensate for a change in risk should be proportional to the magnitude of the risk change. However, a number of studies have shown that this is often not the case, making the estimated VSL measure sensitive to the size of the risk change considered.[26] For example, Beattie *et al*. (1998) in their survey found that a risk reduction of three times the size led to only a 41% increase in CV, with a number of respondents giving identical CV estimates. Tests of the sensitivity of estimates to the size of the risk change considered would also be important in testing the robustness of the results obtained.

6. VSL Estimates and Cost-Benefit Studies of Mine Clearing

To illustrate the importance of VSL estimates in evaluating mine clearance policy we use as an example the cost-benefit study of mine clearance in Cambodia by Harris (2000). Our purpose is not to re-estimate the costs and benefits of mine clearance in Cambodia, but simply to indicate the impact of various VSL measures based on our estimates leaving all other aspects of the work of Harris unchanged.

In his study Harris estimates the cost and benefits of removing mines from 500,000 ha of contaminated arable land, with demining taking place over a period of 25 years.[27] Cost estimates are based on a demining cost of $7,000 per ha, giving a total cost of $3,500m. Although actual expenditure is assumed to be undertaken over the 25 years, the $3,500m is treated as the present value of demining costs. Three major benefits of demining are considered:

- *Saved lives and disabilities*:
  These are valued in terms of the average income earned for the years of productive life remaining. Those injured are assumed to produce half the income of a healthy individual.
- *Medical Costs*:
  These include the initial medical costs of survivors and the on-going costs of artificial limbs for amputees.
- *Gains in Agricultural Output*:
  These are measured as the value-added from previously unused or under-utilized land.

The benefits of the first year of demining and the way in which these are calculated are shown in Table 7 below. Over time these benefits compound as more demining takes place. Using a discount rate of 10% Harris finds a net present value of -$3,434m on an investment of $3,500m. It should be noted that Harris assumes that the completed demining project will save 1,200 deaths and 1,200 injuries per annum. Thus, given the 25 years taken to clear the mines, 1,200/25 new deaths and insuries are saved as a result of a year of demining activity. These assumed casualities are very high. As noted above, 166 deaths and 707 injuries resulted from mine and UXO accidents in 2003-2004.

[26] For a survey and study of this issue see Hammitt and Graham (1999)
[27] Harris (2000) considers a number of scenarios. We will consider only the base case or Assumption Set One.

Table 7: The Benefits of One Year of Demining ($US)*

Production from Saved Deaths[1]	6,432
Production from Saved Disabilities[2]	3,216
Saved Medical Costs[3]	26,400
Value of Additional Agricultural Output[4]	688,000
Total Benefits	724,048

*From Harris (2000) , Table 1, p. 222.
[1] 1/25 of 1,200 deaths x $134
[2] 1/25 of 1,200 injuries x $67
[3] 1/25 of 1,200 injuries x $550
[4] 1/25 of 500,000 ha x 0.40 x $86

The method for determining the benefits of mine clearing used by Harris does not explicitly include a VSL, since estimates are based on the income generated by workers whose lives are saved during the 25 year timeframe. To include VSL estimates we assume that the full value of a life saved is included as a benefit in the year the life is saved. As well as using the results of the survey for the VSL in Cambodia, we also show estimates based on the VSL obtained for Thailand in the earlier study. In 2001/02 income per capita income in Khon Kaen province in Thailand was B25,646, or US$631.6 at the exchange rate used in the Thai study. Harris assumed a per capita income of US$134 in Cambodia. Estimates of the elasticity of the VSL with respect to income give some indication of VSL measures that might be relevant given the income base used by Harris. Miller (2002) suggests elasticities in the range 0.85-1.0, while Viscusi and Aldy (2003) report elasticities of 0.5-0.6. As noted above, pooling across the samples gives and average mean VSL of $248,500 for Thailand. Applying an elasticity of 0.5, gives VSL estimates of $114,461 . In the Cambodian survey the mean injury risk-death risk tradeoffs was 4.63, this is used for all the comparisons considered.[28]

Table 8 below compares the study by Harris with equivalent calculations based on the VSL estimates obtained. None of these VSL measures are large enough to make the present value positive under the assumptions used by Harris, although the present value of benefits becomes a much larger proportion of costs, 17.8-64% compared with 1.9% in Harris.[29] However, even modest estimates make the value of saved lives and injuries the dominant benefit. In Harris the present value of the value-added of the arable land brought into production represents 88% of the benefits of mine clearance, and the benefits of saved lives and injuries only 8.7%. When VSL estimates are used the value of lives and injuries saved dominates benefit assessment, representing 97.3% of the benefits for a VSL obtained from the Cambodian survey. These calculations suggest that estimates of the VSL are likely to drive estimates of the benefits of mine clearing, and would be an important part of the determination of the areas that should be cleared and the degree of demining that should be undertaken in a particular area.

[28] Harris (2001) assumes that the value of a saved injury is half the value of a saved life before taking into account the medical costs associated with injuries.
[29] A VSL of $697,822US would result in a positive net PV in the Harris study.

Table 8: The Impact of VSL Estimates on the Cost and Benefits of Mine Clearance – The Cambodian Case

	Harris (2001) VSL=$1,338[1]	Cambodian Estimate based on the Thailand Survey Elas.=0.5 VSL=$114,461	Ave. Thailand VSL=$248,500	Cambodian Survey Estimate VSL=$443,174
PV of Benefits				
Saved Lives	$3.9m	$464.0m	$1,007.3m	$1,796.4m
Saved Injuries	$1.9m	$100.1m	$217.6m	$388.0m
Saved Lives and Injuries as a Percentage of Benefits	8.7%	90.3%	95.3%	97.3
PV of Mine Clearance	-$3,433.8m	-$2,875.6m	-$2,214.8m	-$1,255.2m
Benefits as a % of Costs	1.9%	17.8	36.7%	64.1%

[1] The counterpart of a VSL measure in Harris (2001), the PV of $134 for 25 years at 10%

6. Conclusion

Reliable estimates of the value of the tradeoff between risk reduction and income generation are necessary to evaluate the desirability of demining in particular locations and the extent of mine clearance that is optimal, and to compare the relative merit of alternative policies that impact on risk, income and economic growth in mine affected communities. Using a survey based approach in two provinces in Cambodia we estimated the VSL at approximately US$440,000. This estimate is much higher than earlier estimates of the VSL in developing economies, which is likely to be due to the nature of the risk being considered and the significant personal experience of the risk among the survey population. Our work also provides estimates of the injury risk-death risk tradeoff and the value of statistical injury.

Future research will assess the reliability of the estimates given possible sources of bias that have been identified in the literature. Estimates of the VSL based on revealed preference or market methods would be useful for comparison purposes.

Applied to a reconsideration of a cost-benefit study of mine clearance in Cambodia, our results suggest that the present value of the benefits are likely to be about 64% of costs compared with 1.9% in Harris (2000). This implies that the degree of mine clearing that can be justified on social efficiency grounds is likely to be significantly higher when VSL methods are used to value lives and injuries saved. Our work also suggests that when VSL measures are used it is likely that the value of lives and injuries saved, and not the value of arable land bought into production, will dominate benefit assessments.

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