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The Value of Statistical Life and the Economics of Landmine Clearance in Developing Countries

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Summary. — This paper presents estimates of the value of statistical life (VSL) in rural Thailand using the contingent-valuation (CV) method. These estimates are applied to an economic analysis of landmine clearance. The estimated VSL of US$250,000 suggests that the value of lives saved from landmine clearance is at least an order of magnitude greater than the values used in existing studies.

Cost–benefit evaluations of landmine clearance are contradictory. 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 farm output—that are worth just 2% of the costs. In Mozambique, the benefits would be worth only 10% of the costs (Elliot & Harris, 2001). Similarly, Mitchell (2004) suggests that landmines are not serious impediments to economic development in Bosnia and Herzegovina, and argues that general promotion of demining as a development action is unwarranted. An exception to these negative results is the study by Harris (2002) of mine clearance in Afghanistan in which a positive net present value is obtained. However, even in that study the value of lives saved and disabilities avoided is only 35% of the total annual benefit of landmine clearance, with more benefit from saving dairy cattle.

As noted by Paterson (2001), the study by Harris (2000) discounts the benefits of mine clearance due to discounting.
clearance, but not the costs, even though the clearance program is spread over 25 years. While discounting costs substantially reduces the size of the negative NPV, the estimated benefits are still only 5% of costs. Paterson also notes that the study by Harris, and by implication the other studies cited above, fail to note that landmine programs involve targeted clearance operations rather than an “average” clearance task so that mine fields with the greatest benefits are likely to be cleared first. For example, Paterson suggests that in Cambodia the clearance of landmines that prevent the use of existing infrastructure or allow new development projects such as access roads, water systems, and irrigation works are likely to yield significant economic returns. As a result, the true economic benefits of real landmine programs are seriously underestimated. A recent cost–benefit study undertaken by Gildestad (2005) shows positive benefit–cost ratios for clearing irrigation systems, water supplies, roads and bridges, school premises, health stations, and historical sites in Cambodia, while costs do not generally cover benefits for the clearance of agricultural lands. Applying these results to the overall Cambodian clearance program in 2004 Gildestad finds that benefits were 38% higher than costs.¹

The conclusions from existing cost–benefit analyses of landmine clearance may have been influenced by inadequate data. These studies value injuries and premature death according to the present value of lost earnings (or lost GDP).² This foregone earnings approach is no longer popular in developed countries because it ignores risk aversion and underestimates the value of life (Rosen, 1988). Instead, developed countries now use estimates of the value of statistical life (VSL). This VSL is calculated either from reports by survey respondents of how much they would be willing to pay to avoid risks (or how much they would need to be paid to accept risks) or from market-based, revealed preference studies. The theoretical superiority of VSL measures is recognized in the landmine clearance literature (e.g., Harris, 2000) but because no estimates exist for countries with landmine problems, imperfect foregone earnings methods are 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 developed countries (Shogren & Stamland, 2002).

While economists may underestimate the value of lives saved from landmine clearance, mine clearance agencies may overestimate 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 (2000) suggest that donors may value the lives saved by clearing mines using standards from their own (rich) countries. Over-valuing saved lives could explain why landmine clearance standards are so strict, requiring 100% removal of mines and UXO (UNMAS, 2003). This standard favors expensive manual clearance because existing machines cannot find every single mine. In contrast, it is socially efficient 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).

The present paper represents the first attempt to estimate the value of statistical life and injury in the context of landmine clearance. The contingent-valuation (CV) method is used to estimate the VSL for a rural population in Northeast Thailand. Currently, landmine and UXO accidents cause about 40 deaths and 130 injuries per year in Thailand. Mines and UXO are present in 530 communities, containing just over 500,000 people. The incidence rate of landmine fatalities and injuries is 34 per 100,000 in the affected communities and 0.28 per 100,000 when calculated for the whole country (SAC, 2003). Landmines are likely to pose a continuing risk for many years. In the three years since mine action units were established, the Thai army has cleared less than 1% of the 2,560 km² of mine-contaminated land.

Perhaps because of the minimal progress, there are no existing cost–benefit studies of mine clearance in Thailand. Therefore, to illustrate the implications of the VSL estimates for cost–benefit studies of mine clearance, we reconsider the study by Gildestad (2005) of mine clearance in neighboring Cambodia. The use of more plausible VSL measures that would follow from our study increases the importance of human benefits relative to development benefits in assessing targeted clearance. These results also show that the value of VSL used is decisive in making judgements about the economic value of clearing agricultural land and in setting clearance priorities. In addition to adding to the literature on 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 knowledge of the value to place on lives 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 VSL estimates 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).

The outline of this paper is as follows. Section 2 reviews existing estimates of the value of lives saved in studies of landmine 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 the 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. The cost–benefit study by Gildestad (2005) 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

Previous studies of landmine clearance have valued lives saved by the present value of lifetime income foregone. These lifetime present values range from US$1,300 to US$25,000 (Table 1). However, it has long been recognized that income foregone (or net income after deducting an allowance for consumption) is inadequate as a basis for assessing the value of lives saved (Rosen, 1988). No value is placed on life itself, the trauma of death, or the psychological affect of living in fear of premature death resulting from a particular risk. Perhaps because of this, the value of lives saved is only a small proportion of estimated total benefits in existing studies of landmine clearance.

A substantial body of literature uses contingent valuation or revealed preference methods to estimate the VSL in a large number of developed countries and for a wide variety of risks. Miller (2000) uses 68 studies, 38 outside the US, 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 14–20 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 countries, so the existing literature on the benefits of landmine clearance may have substantially understated the benefits.

### Table 1. Value of lives saved in previous economic evaluations of landmine clearance

| Author (year)       | Country              | Valuation concept | Annual value [lifetime PV] | Notes                                                                 |
|---------------------|----------------------|-------------------|---------------------------|----------------------------------------------------------------------|
| Harris (2000)       | Cambodia             | GDP per capita    | $134 [1310]               | Reported NPV of −$3,434 m on investment of $3,500 m                 |
| Elliot and Harris (2001) | Mozambique           | GNP per capita    | $140 [1370]               | Reported NPV of −$28 m on $31.4 m investment                        |
| Harris (2002)       | Afghanistan          | Average wage rate | $550 [5,400]              | Reported NPV of $1.265 m on investment of $100 m                   |
| Mitchell (2004)     | Bosnia-Herzegovina   | Annual labor income Household income plus a value for leisure | $2,065 [20,200] $2,000 [25,000] | Positive benefit–cost ratios for some provinces and some types of clearance |
| Gildestad (2005)    | Cambodia             | Household income  | $2,000 [25,000]           |                                                                      |

**Notes:** All present values are calculated at 10% discount rate. PV is present value.

- Based on a 40 year working life.
- Benefits are discounted but costs are not, so the reported NPV is not valid.
- In her own calculations, Mitchell uses a 5% discount rate, giving a lifetime PV of $35,400.
- This is an approximate value, Gildestad calculates a value for both adults and children.
- Section 6 below has more details on the benefit–cost ratios from this study.
3. THE SURVEY

(a) Outline of the approach

Contingent valuation questions were included in a multipurpose survey carried out by the authors in Khon Kaen province, Thailand in September 2003. Khon Kaen is adjacent to landmine-affected areas but is not mined. This may help the contingent valuation method because participants are asked to make comparisons between hypothetical areas with different incomes and levels of risk. These risk comparisons may be less influenced by the perceptions of actual accident risk than they would be in communities directly affected by landmines. The general methodology chosen for the survey was based on that used by Viscusi, Magat, and Huber (1991) in studying chronic bronchitis and auto fatality risk in the US. Perreira and Sloan (2002) have also used this approach in considering disability and death risks in the US. 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.

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, that is, a “risk–money” tradeoff. Other questions were used to determine the tradeoff between the risk of injury from a landmine accident and the risk of death, a “risk–risk” tradeoff.

The risk–money and risk–risk tradeoffs were determined by asking respondents to state their preferences for two different areas in which their village might be located. 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 for landmine clearance, how payments will be made, and exactly what the payments are for. These types of issues would be important for the low income communities involved in this survey. While respondents were not directly asked 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 since risk increases may be valued differently from risk decreases (Viscusi et al., 1991). To provide a test of the sensitivity of results to the way in which the alternatives are presented two questionnaires were used in this study, one that could be interpreted in “willingness to pay” terms and one with a “willingness to accept” focus.

(b) Methodology

A substantial body of literature 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. 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 provided (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, for example, 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 10 villages each with a 1,000 inhabitants and a particular number of deaths or injuries across the villages each year. Showcards were also used to explain and compare risks.

While cost of living differences can be used to represent the money component of risk–money tradeoffs (e.g., Viscusi et al., 1991), these can be hard to explain in low income rural communities where subsistence agriculture provides a substantial proportion of income and where there is no housing market. Instead, in this survey cash income and the change in cash income between areas was used to represent the money component of risk–money tradeoffs. To help respondents think about their current income levels they were asked about their family’s cash expenses during the last month. 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.

(c) 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 Area A and Area B 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 landmine accident, where \( Y \) is total income. Let \( I_a \) and \( I_b \) be the cash income levels in areas A and B 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 areas A and B are \( X_a \) and \( X_b \), respectively. Indifference between the two areas implies that

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

(1)

Again, following Viscusi et al. (1991), assume that the utility function is additively separable in health status and income, and the marginal utility of income is constant and equal to \( \beta \) for the range of income changes considered. Therefore,

\[
u(D) = u(H) - L,
\]

(2)

where

\[
L = \frac{I_a - I_b}{X_a - X_b}
\]

(3)

and \( u(.) \) is the utility function for health status. For example, if \( I_a = B20,000 \), \( I_b = B18,400 \), \( X_a = 0.0004 \) and \( X_b = 0.0002 \), then \( L = B8,000,000 \) or \( u(H) = u(D) + B8,000,000 \). 11

In order to determine the income difference that would make Area A indifferent to Area B for a given change in the risk of death, a respondent was presented with an initial alternative that was then adjusted given the area that was preferred. For example, in Questionnaire One the initial alternatives were

| Area A                  | Area B                  |
|-------------------------|-------------------------|
| Cash income of B20,000 per year | Cash income of B18,400 per year |
| Risk of death per year of 4/10,000 | Risk of death per year of 2/10,000 |

These starting values were chosen to be easily understandable to the respondents, given the average income levels actually prevailing in the area and the desire to express magnitudes of risk that were comprehensible.

If Area B was selected as the preferred area, the cash income in Area B was revised down by B400 and the respondent was asked to reconsider the alternatives. This process continued through a series of up to four iterations until preference switched to Area A or the income in Area A reached B16,800. The questionnaire contained a flowchart that directed interviewers through the iterations (see Appendix 1 for an English version of the Thai flowchart used in data collection). 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 income in Area B would make the areas equally desirable. If this value was inconsistent with the range of incomes implied by the preference switch, this survey response was disregarded. This process provided an additional consistency check. If Area A was selected given the initial alternatives, the cash income in Area B was revised upward by B400 through a series of up to four iterations until Area B was selected or the level of income had reached B20,000. Again, the respondent was asked for the value of income in Area B that would make the areas equally desirable. Questionnaire One is said to have a “willingness to pay” format since the income that was revised was in the area with the lower risk of death.

Questionnaire Two followed a similar procedure to establish indifference. For this questionnaire the initial alternatives were

| Area A                  | Area B                  |
|-------------------------|-------------------------|
| Cash income of B20,000 per year | Cash income of B21,600 per year |
| Risk of death per year of 2/10,000 | Risk of death per year of 4/10,000 |
With this questionnaire, the income in Area B was adjusted to achieve indifference. This is said to have a “willingness to accept” format since the income that was adjusted was for the area with the higher risk of death. The two questionnaires were allocated randomly to the respondents.

(d) 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. While landmine accidents cause a variety of injuries of different severity, including loss of legs, feet, arms, hands, and sight, the particular injury considered was the loss of a leg below the knee. This was established by showing respondents a picture of a mine accident victim whose leg had been amputated below the knee. Given indifference between Area A and Area B, the questions sought to find the risk combination that would make Area A indifferent to Area B, assuming that all other aspects of the areas 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. Let \( X_a \) and \( Y_a \) be the annual probabilities of death and injury in Area A and \( X_b \) and \( Y_b \) be the corresponding probabilities in Area B. Given indifference between Area A and Area B

\[
Y_a u(J) + X_a u(D) + (1 - Y_a - X_a) u(H) = Y_b u(J) + X_b u(D) + (1 - Y_b - X_b) u(H).
\]

It follows that

\[
u(D) = tu(J) + (1 - t)u(H) = u(H) - t(u(H) - u(J)),
\]

where

\[
t = \frac{Y_a - Y_b}{X_b - X_a}.
\]

The tradeoff between injury and death is defined as \( t \). For example, if for Area A \( Y_a = 0.002 \) and \( X_a = 0.0002 \), while for Area B \( Y_b = 0.0012 \) and \( X_b = 0.0004 \), then indifference between the areas would imply an injury-death tradeoff of 4.0.

The procedure used to determine the risk–risk alternatives that made Area A and Area B indifferent for the respondent was based on the same procedure as used for risk–money choices. The initial alternatives used were

| Area A | Area B |
|-------|-------|
| 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 Area A was chosen the number of injuries per 10,000 in Area B was revised down until preference switched or there were zero injuries. A similar flowchart to that used for risk–money tradeoffs was employed (see Appendix 1). 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 Area B was chosen the number of injuries per 10,000 in Area B was revised up in a similar way until preference switched or the number of injuries reached 20 per 10,000.

(e) 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

\[
u(H) - L = tu(J) + (1 - t)u(H), \quad \text{or} \quad u(H) - u(J) = \frac{L}{t}.
\]

(f) Sample characteristics

Respondents for the survey were identified by stratified sampling. Three villages were randomly selected in each of the 10 sub-districts in Ban Phai district and each of the 12 sub-districts in Phon district in southern Khon Kaen province. A random sample of 10 households was drawn in each village, giving an overall sample of 660 households in 66 villages. The CV survey was conducted on a sub-sample drawn from 180 households in 18 of these villages. Respondents were 18 years of age or older, with one randomly selected male respondent and one randomly selected female respondent.
in each household interviewed. Each respondent answered the questionnaire independently, and should not have overheard responses being given by others.

Approximately 16% of responses failed the consistency checks with the willingness to pay (WTP) format, compared with 7% for the willingness to accept (WTA) format (Table 2). This difference was especially apparent in the reporting of a zero VSL, which can be considered as failing a dominance criterion given that the two areas would have had the same cash income, but different risks of death. This difference should not reflect sample differences because questionnaires One and Two were allocated randomly between respondents. Indeed, there is no evidence of significant differences between the two sub-samples in terms of their age, gender, education, income, or personal knowledge of landmine victims.

4. RESULTS

(a) Risk–money tradeoffs and the VSL estimates

The survey responses suggest that the average VSL is approximately US$240,000 when the willingness to pay format is used, and around US$260,000 with the willingness to accept format (Table 3). Framing the questionnaire in a “willingness to pay” form rather than using a “willingness to accept” format has an insignificant impact on the value of statistical life estimates that result \( p < 0.68 \). Therefore, pooling across the two sub-samples is appropriate, and gives an average VSL of US$248,500 (with a 95% confidence interval of US$206,000–US$291,000). The medians are about $50,000 higher for both questionnaires, and for the pooled sample the median is $295,500.

How do these VSL estimates compare with the foregone income approach? During 2001–2002, the value of income per capita in rural Khon Kaen was B25,646 or US$630 (MAC, 2003). For a 40 year working life and a discount rate of 10% the present value of forgone lifetime earnings would equal $6,160, thus the ratio of the mean VSL to lifetime earnings is around 40:1.

The VSL appears to vary significantly between respondents. Figure 1 uses smoothed densities to show the underlying distribution of responses. The distribution is somewhat bi-modal, especially with the willingness to accept format. However, regression analysis (using variables listed in Table 4, below) showed no relationship between observable characteristics of respondents and the probability of being in the higher or lower mode. Instead, the variation appears to reflect underlying heterogeneity in preferences.

Regression analysis revealed that some characteristics of respondents had an influence on their estimated VSL. Older respondents had a lower VSL, with an elasticity of \( 0.29 \) at the mean (Table 4). In other words, those with fewer years left to live appear to place a lower value on risk reductions, which is consistent with some results in the literature (Hammitt & Liu, 2003). Gender, education, and prior

| Table 2. Sample characteristics and consistency checks |
|------------------------------------------------------|
| Sub-sample given “Willingness to Pay” Questionnaire | Sub-sample given “Willingness to Accept” Questionnaire | t-test for significant differences in sub-samples |
|------------------------------------------------------|
| Number of respondents | 171 | 168 |
| Number failing consistency checks | 15 | 8 |
| Risk–money tradeoff | 2 | 3 |
| Risk–risk tradeoff | 11 | 0 |
| Zero VSL dominance failure | 143 | 157 |
| Final sample size | 43.1 | 43.9 | 0.37 \( p < 0.72 \) |
| Age | 0.486 | 0.504 | 0.26 \( p < 0.80 \) |
| Knowledge of mine victims | 0.136 | 0.153 | 0.50 \( p < 0.63 \) |
| Post-primary schooling | 0.220 | 0.161 | 0.63 \( p < 0.55 \) |
| Monthly cash expenditurea | 6,960 | 7,233 | 1.00 \( p < 0.34 \) |

Note: Characteristics are weighted estimates and t-tests correct for clustering, stratification, and weighting. a Baht per household, with approximately B40.6 per US$1 at the time of the survey.
knowledge of landmine victims have no clear effect on the VSL estimates. 18 Neither of two proxies for permanent income (the log of per capita monthly spending and the log of the dwelling value) have significant effects on the VSL estimates. In contrast, previous studies tend to find differences by income levels, although that may be because they span a wider range of incomes than found among these respondents in what is a relatively poor area of Thailand. The insignificance of the questionnaire effect (i.e., using the willingness-to-pay format) that was previously shown in Table 2 persists with the addition of covariates. 19

Table 3. Value of statistical life (VSL) estimates

|                      | Questionnaire one “Willingness to Pay” | Questionnaire two “Willingness to Accept” | t-test for significant questionnaire effect |
|----------------------|----------------------------------------|------------------------------------------|--------------------------------------------|
| Mean VSL (US $)      | 238,963 (18,920)                       | 258,331 (38,493)                         | 0.42 p < 0.68                              |
| Median VSL (US $)    | 283,211 (27,429)                       | 307,838 (48,758)                         | 0.34 p < 0.74                              |

Note: N = 300. The point estimates are weighted. Standard errors in parentheses (and t-tests for questionnaire effects) corrected for clustering, stratification, and weighting. The standard error of the median comes from an intercept-only quantile regression with 100 cluster bootstrapped replications. The VSL estimates for each respondent are obtained by applying Eqn. (3) in the text to the values generated from the survey.

Injury risk–death risk tradeoffs

Table 5 provides summary statistics for the tradeoff 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. According to the indifference estimates provided by the respondents, in these two rural districts the mean tradeoff is 5.1 injuries per death, while the median is six injuries per death. 20 The implied value of a statistical injury resulting in amputation below the knee has a mean of $110,000 (with a 95% confidence
interval of $55,000–$165,000), while the median is $43,000.

The injury–death tradeoff appears to vary widely between respondents (Figure 2). The bimodality from the VSL distribution is also apparent in the tradeoff (by construction). Almost 10% have a tradeoff ratio of less than 1, implying a preference for death over injury. These responses could represent genuine preferences for death rather than injury in low-

Table 4. Regression analysis of factors that may affect VSL estimates

|                          | OLS results | Median regression results |
|--------------------------|-------------|--------------------------|
| Log age                  | −0.286      | −0.185                   |
|                          | (0.143)c    | (0.168)                  |
| Male^b                   | −0.024      | 0.123                    |
|                          | (0.049)     | (0.093)                  |
| No schooling^b           | −0.637      | −1.155                   |
|                          | (0.435)     | (0.740)                  |
| Years of education       | −0.023      | −0.006                   |
|                          | (0.021)     | (0.016)                  |
| Has tertiary education^b | −0.176      | −0.271                   |
|                          | (0.482)     | (0.622)                  |
| Prior knowledge of victims^b | 0.079 | 0.003                    |
|                          | (0.112)     | (0.096)                  |
| Log per capita spending  | 0.068       | −0.008                   |
|                          | (0.183)     | (0.180)                  |
| Log of dwelling value    | 0.060       | 0.041                    |
|                          | (0.90)      | (0.078)                  |
| Survey has WTA format^b  | 0.081       | 0.109                    |
|                          | (0.171)     | (0.277)                  |
| Constant                 | 12.828      | 13.198                   |
|                          | (1.756)**   | (1.775)**                |
|                        | 0.053       | 0.068                    |
|                        | (0.157)     | (0.175)                  |
|                        | Zero-slopes | 17.40**                  |
|                        | F-test^a    | 17.34**                  |

|                          | Mean | Median |
|--------------------------|------|--------|
| Injuries per death at indifference point | 5.1  | 6.0    |
|                          | (0.5 ) | (1.3)  |

Note: Weighted estimates, with N = 300. The dependent variable is the log of the value of statistical life that is implied by the respondent’s choices. For the OLS results, the standard errors in parentheses are corrected for clustering, stratification, and weighting. For the median regression results, the standard errors are based on 100 cluster bootstrapped replications. Dummy variables for the districts within Khon Kaen province are included in each regression.

^a This is an adjusted Wald (W) test: \( (d - k + 1/kd)W \sim F(k, d-k+1) \), where \( d \) is the number of clusters minus the number of strata (12), and \( k \) is the number of slope variables (StataCorp, 2003).

^b Denotes dummy variables.

^c Significant at 10%.

^* Significant at 5%.

^** Significant at 1%.

Table 5. Injury risk–death risk tradeoff ratio

|                          | Mean | Median |
|--------------------------|------|--------|
| Injuries per death at indifference point | 5.1  | 6.0    |
|                          | (0.5 ) | (1.3)  |

Note: Weighted estimates. Standard errors in parentheses corrected for clustering, stratification, and weighting. The standard error of the median comes from an intercept-only quantile regression with 100 cluster bootstrapped replications.
income rural communities for respondents who view an amputee as having a particularly poor quality of life or as a burden to their family.21

5. DISCUSSION

(a) Comparison with the literature

How plausible is the survey estimate of a VSL of US$0.25 million? There is a paucity of VSL figures in developing countries but none of them suggest that US$0.25 million is an overestimate. For example, studies of compensating wage differentials for risk of fatal and nonfatal injuries in India’s manufacturing sector give VSL estimates that range from US$0.15 to $0.36 million (Simon, Cropper, Alberini, & Arora, 1999) to US$1.4–$4.1 million (Shanmugam, 2000, 2001). In a similar study of Taiwan in the early 1980s, when Taiwan might still have been considered a developing country, the VSL averages US$0.41 million (Liu, Hammitt, & Liu, 1997).

There are even fewer contingent valuation estimates of the VSL for developing countries. A survey in Beijing gives a VSL that ranges from US$0.06 to $0.2 million (Zhang & Zheng, 2001). In Taiwan, the surveyed willingness to pay to reduce the risk of death from severe acute respiratory syndrome (SARS) gives a VSL of US$2.8–$11.8 million (Liu, Hammitt, Wang, & Tsou, 2003). This high value, which is similar to the usual range in developed countries, may reflect the high degree of concern abut SARS when the data were collected. Perhaps of greatest relevance to the current estimates are the results of two contingent valuation surveys in urban Bangkok examining air pollution risk and traffic accident risk (Vassanadumrongdee & Matsuoka, 2005). The median VSL from the willingness to pay surveys was US$0.74 million for air pollution risk and US$0.87 for traffic accident risk, while the means were US$1.32 million and US$1.48 million.

The current survey estimate of US$0.25 million appears quite consistent with these results for Bangkok, because the average incomes among the Bangkok samples were approximately four times higher than the rural incomes in Khon Kaen.22 The results are also consistent with those of Simon et al. (1999), with both studies implying a ratio of VSL to lifetime income of about 40:1. Liu et al. (1997) is also supportive, if the income elasticity of the VSL is about 1.0, because incomes in Taiwan in the early 1980s were about twice those prevailing in Thailand now. The studies that extrapolate from VSL estimates in other countries are also supportive. Miller (2000) predicts a VSL of US$450,000 for Thailand (in 2003 prices), based on a regression of previous VSL studies in other countries. Because the current survey
is in a relatively low-income rural area, it would be expected to be below the predicted average VSL for the entire country.

(b) Possible sources of bias in the estimates

The literature suggests that VSL estimates based on contingent valuation methods may be sensitive to a variety of factors that decrease the reliability of the results (Beattie et al., 1998). Two issues that may affect the reliability of the survey used to produce the current results warrant discussion: starting-point bias and sensitivity to the size of risk changes.

In the survey, the respondents were asked to choose between areas that differed in risk and income, with follow-up questions used to improve on the efficiency of this dichotomous choice. These follow-up questions can be interpreted as a limited form of bidding, and as such may be subject to the starting point bias that is believed to affect the bidding method (Hanneman, Loomis, & Kanninen, 1991). The importance of starting point bias has been noted in the literature, although empirical evidence is mixed (Stalhammer, 1996). Perreira and Sloan (2002) use randomly selected initial values to avoid this bias. This approach was considered for the current survey but abandoned because of the increase in the complexity of the survey for interviewers, and the increased number of iterations necessary to find indifference. Testing for starting point bias would be a useful feature of future surveys in developing countries.

The second issue is that all respondents were presented with initial alternatives that involved a change in risk of 2 in 10,000. Several studies have shown that the estimated VSL is sensitive to the size of the risk change considered (Hanneman & Loomis, 1999). 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 we use as an example a recent cost–benefit study of mine clearance in Cambodia (Gildestad 2005). Cambodia has one of the highest rates of civilian casualties from mines and UXO in the world. The war period left an estimated four to six million mines and millions of UXOs in the ground (Gildestad, 2005). It has been estimated that 46% of villages in Cambodia suffer some degree of contamination (CMAA, 2003). From 1979 to 2003 there were approximately 60,000 mine/UXO casualties. While casualties have decreased over time, they have remained at between 700 and 900 per year since 2000 (CMVIS, 2000–2004).

Gildestad (2005) estimates the cost and benefits resulting from the clearance of 1 km² of high priority contaminated land for a variety of uses across the principal mine affected provinces in Cambodia. Two demining cost figures are used based on the costs of existing mine clearance programs, $0.70 m² and $0.90 m². Benefits from clearance include human benefits, the value of casualties and medical costs saved, and development benefits, revenue from new production or tourism and travel costs saved.

To estimate human benefits it is assumed that clearance reduces relevant casualties in proportion to the area of land cleared to 10% of the current rates. The value of casualties is based on the productive value of victims assuming a present adult income of $1,000, with an additional amount of $1,000 for the value of leisure. Adult productive income is assumed to grow at 3.5% per annum for 10 years and 2.5% thereafter. Adults work for 35 years and children are treated as having five unproductive years followed by 40 years of work. For fatalities full productive value is lost, for amputees it is assumed that 70% of productive value is lost, while for other injuries 40% of productive value is lost.

The methods of estimating development benefits depend on land use. For agricultural land and irrigation systems they are based on the additional value of farm revenues. For roads and bridges, wells and water supplies, schools, and health stations estimates are based on reductions in travel costs, while for historical and cultural sites additional tourist revenue is calculated. All future benefits are discounted at a rate of 10%. Costs are assumed to be incurred in the current period.

The method used by Gildestad to value the human benefits of mine clearing does not explicitly include a VSL estimate. To show the impact of VSL estimates we assume that the full value of a life saved is included as a benefit in the year the life is saved. Household annual
income in the area of Thailand where the VSL estimates came from is approximately $2,872. We assume a value of household income of $700 for Cambodia based on the figures provided by Gildestad. The estimates of the elasticity of VSL with respect to income give some indication of the VSL measures that might be relevant given this income base. Miller (2000) suggests elasticities in the range 0.85–1.0, while Viscusi and Aldy (2003) report elasticities of 0.5–0.6. Using the mean VSL of $248,500 for Thailand, and applying elasticities of 1.0 and 0.5, gives VSL estimates of $60,546 and $122,661. We also show the results when using the mean VSL for Thailand, which would apply to Cambodia if it was an elasticity of zero.

Gildestad distinguishes between adults and children in calculating the human benefits of clearance. In his model, an adult life saved in the first year would have a present value of approximately $25,000 compared with a value of $21,000 for a child’s life saved. In applying our VSL estimates we have ignored possible differences between adult and child VSL measures. VSLs can also be expected to change over time as the real incomes increase. We apply the growth assumptions used by Gildestad and the three elasticities above to revise the VSL estimates for lives saved in the future.

The mean injury risk–death risk tradeoff of 5.1 is used to estimate the value of reductions in amputations. Following Gildestad, we assume that the value of reductions in other injuries is 57% of the value of an amputation saved.

Table 6 compares the results obtained for the clearance of agricultural land by province obtained by Gildestad given a clearance cost of $0.90 m² with the equivalent calculations based on our VSL estimates. For all but Pailin province the estimates obtained by Gildestad suggest that the clearance of agricultural land is uneconomic. Given VSL values equivalent to those in Thailand clearing agricultural land would be economic in all but two provinces. For VSL measures based on an income elasticity of 0.5 clearing agricultural land in four of the nine provinces would be economic. Thus, for agricultural land the VSL measure used is likely to be decisive in making judgments about the economic value of clearance and in setting clearance priorities.

For other types of land use considered by Gildestad the value of productive benefits are much larger, dominating cost–benefit calculations. The inclusion of VSL measures acts to increase the importance of human benefits and the magnitude of the benefit–cost ratio. Table 7 compares Gildestad’s results for land use types with those obtained based on our VLS estimates.

### Table 6. Benefits and costs for the clearance of agricultural land in Cambodia by province

| Province      | Human loss % of benefits | Benefit–cost ratios |
|---------------|--------------------------|---------------------|
|               | Gildestad (2005)         | VSL 0.0b  | VSL 0.5c | VSL 1.0d | Gildestad (2005) | VSL 0.0b  | VSL 0.5c | VSL 1.0d |
| Battambung    | 60%                      | 86       | 78      | 67      | −0.45      | 0.56     | −0.03    | −0.35    |
| Pursat        | 17%                      | 44       | 31      | 20      | −0.54      | −0.31    | −0.44    | −0.52    |
| Siem Reap     | 25%                      | 57       | 43      | 30      | −0.71      | −0.49    | −0.62    | −0.69    |
| Otdar Meanchey| 38%                      | 71       | 58      | 44      | −0.29      | 0.52     | 0.05     | −0.21    |
| Banteay Meachey| 62%                     | 87       | 79      | 68      | −0.49      | 0.45     | −0.10    | −0.40    |
| Patin         | 50%                      | 80       | 69      | 56      | 0.36       | 2.36     | 1.19     | 0.55     |
| Kampong Thom  | 60%                      | 80       | 78      | 67      | −0.32      | 1.03     | 0.26     | −0.16    |
| Kampong Cham  | 33%                      | 66       | 52      | 39      | −0.20      | 0.59     | 0.13     | −0.12    |
| Preah Vihear  | 52%                      | 78       | 67      | 54      | −0.38      | 0.50     | −0.02    | −0.30    |
| Average/others | 47%                     | 76       | 64      | 51      | −0.38      | 0.45     | −0.03    | −0.30    |
| Raw average   | 44%                      | 73       | 62      | 50      | −0.34      | 0.57     | 0.04     | −0.25    |

* a Original calculations are by Gildestad (2005) and assume a cost of clearance is $0.90 m².
  b Uses the VSL estimate of $248,500 for Thailand, assuming a zero elasticity of the VSL with respect to income.
  c Uses the VSL estimate of $122,600 based on an elasticity of 0.5 of the VSL with respect to income.
  d Uses the VSL estimate of $60,500 based on an elasticity of 1.0 of the VSL with respect to income.
  e Average/others is for over all provinces.
  f Raw average is the unweighted average across provinces.
7. CONCLUSION

Economic evaluation of landmine clearance, and other interventions to reduce risk in developing countries, requires knowledge of the value to place on lives saved. Existing studies use the present value of foregone income, which is no longer the preferred approach in developed countries. Using a survey based approach in Khon Kaen province in Thailand we estimate an average value of statistical life of US$250,000. This estimate is broadly consistent with what little is known about the value of statistical life in developing economies.

These results may have major implications for demining policy and for other risk reduction efforts in developing countries. Because our estimate of the value of statistical life is about 40 times the present value of income foregone, the degree of mine clearing that can be justified on social efficiency grounds is likely to be significantly higher than when lifetime income is used to value lives saved. More broadly, the results emphasize the need for reliable estimates of the value of statistical life when evaluating the desirability of risk reduction interventions in developing countries.

NOTES

1. We are indebted to a referee for emphasizing the importance of targeted clearance and referring us to Gildestad (2005).

2. Gildestad (2005) also includes an allowance for the value of leisure time.

3. For a survey of early studies of the valuation of life and a critique of these studies see Jones-Lee (1976), Harris (2000), Harris (2002), Elliot and Harris (2001), and Gildestad (2005) do not value the psychological costs associated with the risk of death.

4. For a now dated, but useful review see Viscusi (1993). For a recent critical review of market based estimates see Viscusi and Aldy (2003). Nordhous (2002) shows how VSL measures can be used to measure “health income.”

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. The probabilities were chosen to present an easy to interpret, small change in risk, while avoiding zero risk alternatives. The Landmine Impact Survey for Thailand, SAC (2003), proposes an estimate of 34.35 mine incident victims for 100,000 people per year.

7. This assumption is less restrictive than it may appear because the income changes used in the questionnaire are equivalent to only 1.6% of mean income in this region of rural Thailand. Moreover, Herriges and Kling (1999) provide evidence that welfare estimates from models of discrete choice which assume constant mar-
ginal utility of income are very close to the estimates from much more complex nonlinear models.

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

9. This would correspond to a VSL of US$197,016 using the average exchange rate over the period during which the survey was undertaken of US$0.024627 per Baht.

10. 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.

11. Because there were no previous estimates of VSL for Thailand to provide guidance about whether these starting values would be widely at variance with what might be expected for the VSL, they were also compared with the predicted VSL for Thailand calculated by Miller (2000).

12. The flowchart that directed interviewers through the iterations is similar to that used when Area B was initially selected as the preferred area, so is not presented in Appendix 1.

13. In Thailand, over 50% of mine accidents result in amputations, with the loss of a leg, either above or below the knee, the most common serious injury (SAC, 2003).

14. 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.

15. To reduce the number or iterations the last step involved a decrease of four injuries per 10,000.

16. 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.

17. Using an Epanechnikov kernel with a bandwidth of $50,000.

18. A referee raised a concern about multicollinearity affecting the results because of the possible high correlations between the variables “No schooling,” “Years of education,” and “Has tertiary education.” However, the results are unchanged if any two out of these three variables are dropped from the regression. Moreover, the largest variance inflation factor (VIF) was only 2.48 and the mean of the VIF's was only 1.39, which is less than the thresholds suggested for detecting multicollinearity (StataCorp, 2003).

19. Although not reported in Table 4, the questionnaire effect is also statistically insignificant if a more general model is used with both slope and intercept dummy variables for the WTA format. The joint test of equal slopes and an equal constant between the two samples is $F_{9,4} = 3.13$ ($p < 0.15$). This test accounts for the weighted, clustered and stratified nature of the samples.

20. The difference in questionnaire formats for the VSL estimates (willingness to pay versus willingness to accept) has no statistically significant effect on the mean tradeoff ratio ($p < 0.54$).

21. Viscusi et al. (1991, p. 45), report a similar result from a risk–risk analysis.

22. The sample used by Vassanadumrongdee and Matsuoka (2005) appears to be from a richer than average area of Bangkok, with average incomes one-third higher than the average for all Bangkok.

23. We would like to thank Julien Chevillard of the United Nations Development Program for providing a copy of this study and Bjørn Gildestad from the Nordic Consulting Group for assistance in interpreting the analysis.

24. While Cambodia has the highest rate of recorded casualties, it is estimated that actual rates are significantly higher in Afghanistan. We would like to thank a referee for this observation.

25. As pointed out by a referee, this should not be interpreted as suggesting that clearance programs have had no effect on accident rates. Internal migration, informal demining by villagers and tampering have added to casualty numbers.

26. Relevant casualties are assumed to include all mine casualties and 30% of UXO casualties. UXOs are more dispersed and thus casualties are less likely to decline as a result of targeted clearance programs.

27. Although Gildestad does not use a VSL measure, his estimates are based on a current annual income per victim of $1,000 compared with household income in Cambodia estimated to be between $300 and $700. His estimates include an additional $1,000 for leisure. Although arbitrary, these assumptions do make human benefits closer to those expected from a VSL estimate.
comparison, Harris (2000) assumes a productive income per victim of $134 per year.

28. This is based on a per capita income of $630 noted above and a household size of 4.56.

29. The benefits obtained are likely to underestimate the benefits from clearing agricultural land. As noted by Paterson (2001) the clearance of highly productive land would normally be targeted first.

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APPENDIX 1. EXTRACT FROM THE CONTINGENT VALUATION QUESTIONNAIRE

10. “We now want to ask you more about changes in the risk of being killed by a landmine.”

“Consider the following two areas in which your village could be located. Which do you prefer, taking into account the differences in the risk of death and the differences in your cash income? Remember that all other aspects of the two areas are the same and similar to the current area in which you live.”

Write the B 18,400 on the second comparison sheet (Area Two).

Show the interviewee the visual aid representing these risks (marked Question 10, Area One and Area Two).

| Area One                                      | Area Two                                      |
|-----------------------------------------------|-----------------------------------------------|
| • You have a cash income of B20,000 per year   | • You have a cash income of B________ per year |
| • There is a risk of FOUR DEATHS from landmines over 10 villages per year | • There is a risk of TWO DEATHS from landmines over 10 villages per year |
| • You have the same amounts of your own products to consume as in your own village | • You have the same amounts of your own products to consume as in your own village |

If **TWO** is chosen initially,
Tick the symbol (√) in the □ whether the **ONE** or **TWO** is chosen
Change the amount of money in **TWO**, and ask the interviewee to reconsider
18,400
Go to arrow point

18,000
Go to arrow point

17,600
Go to arrow point

17,200
Go to arrow point

16,800
Go to arrow point

Two is chosen

One is chosen

Two is chosen

One is chosen

Two is chosen

GO TO
10 (b)

10(b) Ask: “What value of cash income would make Area One and Area Two equally desirable for you given the difference in the risk of death from landmines?” (Please Specify:———————). Go to the end of this question.

(See Overleaf)
12. “We now want to ask you more about risk of death and of injury from landmines.”

“Consider the following two areas in which your village could be located. Which do you prefer, taking into account the differences in the risk of death and the risk of injury? Remember that in all other respects the areas are the same.”

Write in the 12 on the second comparison sheet for this question (Area Two).

Show the interviewee the visual aid representing these risks (marked Question 12, Area One and Area Two).

| Area One                                      | Area Two                                      |
|-----------------------------------------------|-----------------------------------------------|
| • There is a risk of TWENTY INJURIES from landmines over 10 villages per year | • There is a risk of ________ INJURIES from landmines over 10 villages per year |
| • There is a risk of TWO DEATHS from landmines over the 10 villages per year | • There is a risk of FOUR DEATHS from landmines over the 10 villages per year |

FLOWCHART FOR QUESTION 12

If TWO is chosen initially,
Tick the symbol (✓) in the □ whether the ONE or TWO is chosen
Change the amount of injury in TWO,
and ask the interviewee to reconsider.
12(c) Ask: “What number of injuries would make Area One and Area Two equally desirable for you given the difference in the risk of death from landmines?” (Please Specify: ————-). Go to the end of this question.